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Crop Improvement in Eastern and Southern Africa

Research Objectives and On-Farm Testing

A regional workshop held in
Nairobi, Kenya, 20-22 July 1983

ROCEEDINGS

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Crop Improvement in Eastern and Southern Africa:

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Editor: Roger A. Kirkby

RÉSUMÉ

Un atelier a réuni un petit groupe représentatif de scientifiques travaillant à des programmes d'amélioration des cultures alimentaires en Afrique orientale et australe, pour discuter de la planification, de la conduite et de l'élaboration de ces programmes. Le débat a porté surtout sur les aspects méthodologiques, communs à la majorité des cultures réalisées par les petits fermiers et les plus susceptibles de permettre l'utilisation des résultats de la recherche.

On s'intéresse donc ici aux cultures locales et aux pratiques culturales, à l'organisation de l'aide institutionnelle pour améliorer les cultures, aux objectifs particuliers des programmes et au mode d'établissement de ces objectifs, enfin aux méthodes d'évaluation employées pour formuler une nouvelle recommandation sur les travaux de vulgarisation. On résume aussi la séance de discussion qui a porté sur l'organisation des programmes d'amélioration des cultures, l'établissement des objectifs techniques, l'application des critères de sélection, la méthodologie pour les essais tous terrains et sur les fermes et, enfin, l'orientation de la recherche.

RESUMEN

Este seminario reunió un pequeño grupo representativo de científicos que trabajan en programas de mejoramiento de cultivos alimenticios en Africa oriental y meridional con el ánimo de discutir la planificación, la ejecución y el desarrollo de tales programas. El énfasis de la discusión recayó en aquellos aspectos metodológicos, comunes a la mayoría de los cultivos sembrados por los pequeños agricultores, que tienen la probabilidad de influir más en que los resultados de la investigación sean utilizados por el agricultor.

Entre estos trabajos se encuentran breves recuentos de las variedades locales y las prácticas de cultivo empleadas actualmente, la organización institucional para el fitomejoramiento, los objetivos específicos de los programas y su sistema de establecimiento, así como los procedimientos de evaluación empleados para llegar a las nuevas recomendaciones para los trabajos de extensión. También se incluye en este volumen un resumen de la sesión de discusión sobre la organización de los programas de fitomejoramiento, la fijación de los objetivos técnicos y la aplicación de los criterios de selección y la metodología para las pruebas tanto en fincas como en localización múltiple. Varios temas de política fueron identificados.

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FOREWORD

The contribution of breeding and selection to increased food production has been well documented. It has been greatest for crops grown in environments with irrigation or dependable rain, in which farmers have access to fertilizers. Where weather, soil quality, and fertilizer availability constrain production, and the predominant farm type is complex because several crops and animal species are produced, crop improvement has been less successful.

This workshop addresses the need for crop-improvement programs to assure that breeding objectives, screening techniques, and performance evaluation take into account farmers' objectives. R. Bruce Scott, IDRC's Regional Director for Eastern and Southern Africa, expressed this concern in his closing remarks to the workshop: "Scientists must clearly define the group they are seeking to serve and gain a better understanding of its environment. This is necessary to ensure that the problems being tackled are really the problems of the people, and not those only perceived to be problems by the scientists. To be appropriate, therefore, the scientists' methodology should include full dialogue with the target group, who participate in testing the scientists' ideas and become an integral part of the research and development activity."

Several papers in this proceedings point to the need to include on-farm evaluation of genetic material in crop commodity research. As well, close collaboration between farming systems research groups is needed in setting priorities and breeding objetives and in developing on-farm evaluation techniques. The summary of discussions lists specific means to achieve these ends, and provides a very practical and useful guideline for many commodity and farming systems researchers.

Thanks are extended to Professor John H. Monyo of the University of Dar es Salaam and Chief of the Research and Development Centre of the Food and Agriculture Organization of the United Nations (FAO) for his willingness to chair this workshop. His extensive experience in crop improvement and commitment to agricultural research contributed immensely to the discussion sessions, and his rapport with participants ensured that the workshop was conducted in a lively, constructive, and friendly manner. Likewise, appreciation is expressed to the authors, Dr. Moses Onim who organized the field tour, Roger Kirkby who developed the idea of the workshop and took responsibility for its organization and editing, Robert Drysdale for his invaluable assistance in preparing these proceedings, and the small committee comprised of Dunstan Malithano, Gordon Potts, and Robert Zeigler who assisted in the compilation of the summary of discussions.

Hubert G. Zandstra
Director
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INTRODUCTION

METHODOLOGICAL ISSUES RELATED TO FOOD-CROP IMPROVEMENT IN EASTERN AND SOUTHERN AFRICA

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HISTORICAL BACKGROUND

Crop improvement, defined here as a series of research activities resulting in the production of new germ plasm and crop-management practices that benefit the producers and consumers of a crop, has a long history in eastern and southern Africa. A large amount of rigorous scientific work has been conducted, often with relatively rudimentary facilities, since the first research stations were established (e.g., Umbeluzi station, Mozambique, 1903). Initially, research concentrated upon cash and particularly export crops, with a few notable exceptions such as the Tanzania sorghum program that began in 1947 (Doggett 1970). Research on subsistence food crops has developed mostly since 1960, with much of it coming after Leakey's (1970) review. During the past decade, five trends have developed in food-crop research, and it is these trends that have provided the background for this publication.

The first trend has been the gradual expansion of crop-improvement research to encompass a wider range of crop species. In most countries, improvement of subsistence food crops began with only one or two commodities of primary importance -- often maize because of its extensive use in areas of high cropping potential and popularity among the growing populations in urban centres (Harrison 1970). Early in the 1970s, the resources devoted to sorghum research increased as the importance of this crop for the much larger areas of relatively low cropping potential in semi-arid environments, and for the generally poorer rural populations living there, was realized. Mushonga, in his presentation, describes the new focus of sorghum and millet research in Zimbabwe since independence added to the research mandate a new type of clientele, the communal farmer, whose land generally has less cropping potential and who has different requirements for technology. Improvement programs for grain legumes and oilseeds, for example, began partly due to concerns over nutritional issues related to the availability of protein and concentrated calorie sources.

More recently, increased attention has been given to cassava and sweet potato research, which have a long but rather sporadic history in the region. This is partly a result of more farmers in eastern

Africa turning to these crops as sources of food and cash income because they are unaffected by the vagaries of government-controlled crop pricing and marketing systems (Kirkby 1983).

In the near future, we are likely to see this general trend extend to the formation of new programs for other traditional crops that have been even more neglected by research. These include bananas and plantains (staple food crops in large areas of Rwanda, Burundi, Uganda, and Tanzania) and indigenous species of leafy vegetables, which in many places provide an essential component of the family diet in return for very few inputs. The papers by Osiru and Mukiibi and Kwapata and Edje describe proposed research in these two areas.

It is pertinent to ask whether or not there are lessons to be learned from well-established programs by those launching new research efforts. If so, the chances of developing technology that will be used by and benefit farmers within a reasonable period of time might improve. This workshop was planned, in part, to provide an opportunity for the exchange of such information.

REGIONAL COOPERATION

Indigenous research capacity has expanded as universities increase their output of agricultural graduates and a greater number of postgraduates take up research posts within national institutions. Many research programs are now staffed entirely by local scientists.

Indigenous staffing, largely responsible for the rising interest in traditional food crops, has greatly increased opportunities for planning and conducting sustained research programs. It has not always been accompanied, however, by adequate communication and sharing of technical experience among countries, despite many environmental similarities and the use of similar cropping systems. The demise of the East African Community in 1977 resulted in the cessation of the biennial Eastern African Cereals Research Conferences and the dissolution of the East African Sorghum and Millets Improvement Programme (although the core of this program has continued as the national program of Uganda, as described in the paper by Esele). Since 1977, therefore, most scientists have had few opportunities to meet with their colleagues to discuss the status of crop-improvement research.

Fortunately, the development of a series of regional programs linking national efforts is a second detectable trend. It was set by Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and Centro Internacional de la Papa (CIP) in initiating eastern African regional programs for wheat and potato, respectively, and has been followed by regional coordination for research on sorghum (Semi-Arid Food Grains Research and Development (SAFGRAD)), maize (CIMMYT), highland oilseeds (IDRC), and cassava (International Institute of Tropical Agriculture (IITA)) and groundnuts in southern Africa (International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)). These regional activities provide considerable potential for exchanging germ plasm and ideas and for peer-group review (Gebrekidan 1982; ISAR 1982). Regional activities are, perhaps, most effective when organized on a modest scale to be responsive to the needs expressed by scientists in national programs.

ORGANIZATION OF CROP-IMPROVEMENT PROGRAMS

The third trend in crops research has been the organizational focus on multidisciplinary crop-commodity research teams. Typically, a full team would include a plant breeder, an agronomist, and relevant disciplines from the plant-protection field. Originally, only research on cash crops was organized in this manner, but now an increasing number of national teams has been formed to study the major food crops as research resources, particularly trained personnel, become available.

Formation of a multidisciplinary team is a necessary, but not entirely sufficient on its own, condition for ensuring that crop-improvement research is tackled in a holistic manner, with a rational set of priorities among the objectives. Excessive specialization during postgraduate training can make effective cooperation more difficult. Efficient use of limited personnel resources within a country, however, can present other problems with respect to coordination, particularly when national responsibility for research rests with a government agency and many well-trained scientists reside in the university. The paper by Shekour discusses some of these issues as they relate to Ethiopia, where an elaborate system of annual planning and evaluation meetings has been developed to coordinate research undertaken cooperatively by different institutions within a large and ecologically varied country.

A second organizational issue is the triangular relationship among the crop-improvement program, the extension service, and the farmer. The need for information exchange between crop-improvement researchers and farmers is discussed in the next two sections. As well, the presentation by Haile addresses one approach to the subject.

FARMING SYSTEMS RESEARCH

A fourth trend appearing in most countries has been the development of programs for cropping systems research or farming systems research (FSR). This move represents a convergence of views of technically-trained agricultural scientists who are conducting research to improve farmers' intercropping systems (Keswani and Ndunguru 1980) and agricultural economists seeking a more appropriate role in technology generation than ex post evaluations. The introduction of FSR (reviewed by Collinson (1982)) represents an attempt to institutionalize a set of procedures for developing useful new technology that should be more rational and realistic than if each commodity research program were to continue pursuing, in isolation, a strategy for increasing the production of a particular commodity. An example of the effect of the commodity orientation upon a program's objectives is seen in crop-substitution experiments aimed at removing interference from other crops that farmers grow in association or rotation with the commodity of interest.

Farmers do not plan the production of one crop in isolation from another and a program's objectives may change depending upon whether or not this fact is taken into account (Collinson 1968). Some crop-improvement programs already do this, and some may feel that their current priorities, arrived at through good judgment on the part of the technical staff, should merely be confirmed by formal FSR. Percy (1975), for example, believed that most plant-breeding and insect-control research on cotton in western Tanzania would not have been different if an explicit orientation toward farming systems had been used because new cotton varieties gave greater benefits under the adverse conditions found on farms than under the maximum-yield conditions applied to most experiments. This occurred because a major selection criterion had been resistance to jassid leafhoppers, an important yield-limiting factor, especially for farmers who cannot afford insecticides. On the other hand, Percy felt that a FSR orientation would have changed the design of agronomic research, which had developed high-yielding practices based upon increased labour inputs (e.g., making ridges) that may not have been feasible. It is now accepted that peasant farmers experiment with new methods of growing crops, introduce new species or varieties (Nankumba 1979), and show a keen interest in new technology developed at research stations when they feel there is a need. The fact that many existing agricultural recommendations have not been more extensively adopted by small-scale farmers and crop production in Africa is failing to keep up with or surpass the rate of population growth cannot be attributed solely to infrastructural or extension-service deficiencies; first, the technology must fit the farmers' needs and situation.

FSR programs are intended to complement crop improvement and other research station-based activities by conducting interdisciplinary on-farm research in defined areas of the country. By eliciting the participation of farmers, it is hoped that an improved understanding of the constraints and underexploited potential of the systems in the area can be gained and opportunities for technology generation and testing and adaptation of technology to local circumstances, if necessary, can be identified.

Gaining a better understanding of what one sets out to improve upon is common sense, but implementing this strategy can present several problems, particularly where the number of trained personnel capable of conducting conventional research is still inadequate. Eicher and Baker (1982) have suggested that, because FSR depends so much upon there being strong commodity research to provide the basis for technical innovation, the overenthusiastic introduction of FSR could divert critical resources away from crop improvement. Certainly, research institutions need to address the question of what constitutes a strong program for crop improvement. Is strength measurable in terms of budget and personnel, by a program's impact on the well-being of producers and consumers, or its ability to make use of new information on farmers' needs? Crop improvement and FSR need to cooperate closely, but their interrelationships at present are neither well defined nor obvious. At the same time, crop-improvement programs may find increasing difficulty in integrating national priorities with the narrowly defined priorities identified at the farm level as more on-farm work reveals differences between farming systems that call for subsets of objectives and criteria for different groups of farmers. Crop-improvement programs require effective linkages at the national level with other disciplines in addition to those involved in on-farm research if they are to generate useful technology, particularly in the field of postharvest technology and food utilization. The sorghum breeder, for example, cannot necessarily decide alone, or even in conjunction with the FSR economist and agronomist, the appropriate grain type to use as a selection criterion in developing new cultivars for an area where farmers currently grow white grain types but suffer serious losses to birds. Brown-seeded bitter types that deter birds could be a better option but only if dehulling equipment, capable of producing a quality of grain that is acceptable to the consumer, can be manufactured and distributed (Forrest and Yaciuk 1980).

RESOURCE-EFFICIENT AGRICULTURE

The fifth recent trend in research orientation is the emphasis given, for several reasons, to increasing production while maintaining relatively low levels of inputs. Sometimes this is due to a redistribution of the population to drier, lower cropping potential areas of a country in response to pressures on land elsewhere (e.g., Kenya, as pointed out in Onim's paper); the enfranchisement of a poorer group of farmers previously ignored by research, as in Zimbabwe (see paper by Mushonga); concern that the benefits of agricultural research should reach the poorest farmers; and a shortage of foreign exchange for importing agricultural chemicals (Nyerere 1983). Multilocation testing of new crop cultivars has long been the standard technique for taking into account the heterogeneity of soils, climate, and pest distribution within a country (e.g., a national network of sites has been particularly well developed in Uganda, as discussed in the paper by Esele). However, less productive soil types are typically underrepresented on experimental stations and other managed sites due to earlier emphasis upon large-scale agriculture and cash cropping. Fertility levels and weed flora also tend to become unrepresentative of surrounding farms due to intensive management. This has led to concern over the adaptation and utility of varieties developed under and for high-input conditions (IITA 1982). The diamond design of treatments to verify the performance of a new cultivar and management practice under both recommended and farmers' conditions is a technique now widely used to test for interactions before the final release of recommendations. This 2^2 design was first made popular by Allan (1969) in eastern Africa.

The evaluation of technology, through feedback, can assist in the design of appropriate program objectives, but a program that sets out to develop resource-efficient technology would probably want to introduce relevant criteria at an earlier stage by examining existing systems. Traditional low-input systems are often highly complex and incorporate compensatory mechanisms that reduce the risk of total failure during a poor season but may limit responsiveness to more favourable conditions. In Somalia, climatically the harshest of the three countries reporting on sorghum research at this workshop, sorghum is not only a food crop but also provides the straw required for feeding livestock, which generally comprise the most stable component of the farming system. Furthermore, much of the crop is ratooned to ensure the growth of a small second crop without recultivating during an unreliable rainy period, even though a second sown crop would have the potential to produce a greater yield (see paper by Hashi).

If farmers' strategies suggest that improved resource-efficient cultivars may be different in habit from those developed under a high-yield objective, programs need to ensure that the internal allocation of resources reflects a logical set of priorities. This may include a decision on whether to breed for two or more distinct sets of conditions or retain and advance carefully selected segregants for ultimate testing under the diverse range of conditions. Developing recommendations for suboptimal conditions and low-input levels is still a controversial topic and may cause a crop-improvement program to devise its own novel set of selection criteria, which may differ from those traditionally found in textbooks on plant breeding.

Similarly, when evaluating technology, the disciplines involved in crop improvement are usually less familiar with the procedures for conducting realistic on-farm tests than they are with collecting local germ plasm from farmers. The presentations by Zeigler and Manassé and Onim suggest two possible ways of conducting such evaluations.

OBJECTIVES OF THE WORKSHOP

This workshop was organized by IDRC to bring together a small representative group of scientists working in food-crop improvement programs in eastern and southern Africa to discuss planning, conducting, and developing such programs. The intention was to concentrate upon those methodological aspects, common to most crops grown by small-scale farmers, that contribute most to the likelihood that the research results will be utilized by the farmer.

The participants were asked to prepare brief accounts of the local varieties grown and cultivation practices currently employed in their country, institutional organization for crop improvement, specific objectives of their programs and how these were established, and evaluation procedures used in arriving at a new recommendation for extension. Comments were also requested on any modifications that had been introduced into the objectives or evaluation procedures, including reasons for the changes. The reports submitted form the bulk of these proceedings.

During the workshop, the participants were divided into three working groups and asked to discuss and formulate guidelines or recommendations applicable to crop-improvement programs in the region along the following three interdependent themes and any others agreed upon by the participants.

(1) Organization of crop improvement programs -- This involves (a) the mechanisms for effective coordination of crop-improvement activities when more than one scientific discipline or research institution is involved and/or the crop is grown in more than one distinct agroecological region or under more than one type of farming system within the country; (b) the relationships between crop improvement and farming systems research programs with respect to designing and evaluating crop technology; (c) the roles and organization of multilocation and on-farm testing and their linkages with crop improvement, farming systems research, and extension; (d) procedures for the release of a variety or agronomic recommendation; and (e) appropriate training for young scientists joining multidisciplinary crop-improvement programs.

(2) Setting technical objectives and the application of selection criteria -- Topics discussed included (a) useful sources of information on the specific requirements of producers and consumers for new cultivars or management practices; (b) methods by which programs might improve their definition of the technical objectives and selection criteria and may assign priorities to the objectives; and (c) the implications, at the crop-management level, of the technical objectives set for field experiments.

(3) Methodology for multilocation and on-farm testing -- This theme involved discussions on (a) the differences in functions among multilocation testing, researcher-managed on-farm testing, and farmer-managed on-farm testing; (b) approaches to the selection and management of multilocation-testing sites; and (c) selection of on-farm testing sites, methods of eliciting farmer participation in conducting and evaluating on-farm tests, management of experimental and nonexperimental variables, and the types of data to be recorded and methods of combining the analyses of several parameters and comparing analyses across sites.

A summary of these discussions forms the final chapter of these proceedings.

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CEREALS

SORGHUM RESEARCH AT SERERE, UGANDA

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Sorghum research in Uganda is carried out at Serere Research Station in Eastern Uganda, an important sorghum- and millet-growing area. In this area, farmers require cereal crops that produce high and reliable yields. The area has a bimodal rainfall that makes it possible to grow two generations of the crop each year.

Sorghum is the second most important grain crop in Uganda, after finger millet. It occupies about 37%, in pure stands, of the total cultivable acreage in Uganda. In the banana-growing areas of Western and Southern Uganda, sorghum is planted twice a year or as a ratoon crop. In the drier northeastern portions of the country, sorghum is intersown with finger millet. Some farmers also grow the crop in mixtures with maize, simsim, and pigeon peas.

Sorghum may be used unmixed for food in Kigezi and parts of the east and north, especially in Karamoja. Generally, food is prepared from a mixture of sorghum with cassava or sweet potato flours. It is used for making beer throughout Uganda and is grown solely for this purpose in the banana-growing areas. In Kigezi, the grain is germinated with wood ash and dried. The resultant malt makes a sweet porridge (uji).

The crop grows well during both seasons, but birds can be troublesome and attack food varieties at certain times. In the north and east, bitter types are planted during the first rains, when birds are a menace; but during the second rains, very palatable sorghums can often be grown without bird damage. It is an excellent second rains crop and the groundnut/sorghum rotation is highly recommended and practiced--the groundnuts being lifted as soon as they are ready and the sorghum planted immediately. The crop is also useful as a second rains opening crop, with the land being opened to sorghum during the first rains, followed by cotton during the main rains. Sorghum or sorghum and millet are not grown continuously on the same land because this results in the parasitic witchweed Striga becoming abundant.

There are many local varieties and these are still recommended in high-altitude areas such as Kigezi. The local types are also the best for making banana beer. In the north and east, which are generally intermediate to lowland and unreliable rainfall areas, the improved varieties of Serena, Seredo, and E 525 HT are recommended and have been released to farmers because they are better yielding, have shorter maturation periods, and are reasonably resistant to Striga and shootfly.

Research on indigenous sorghum was started at Serere by the Department of Agriculture in 1952. The project gained importance in 1958 when it was taken over by the then East African Agriculture and Forestry Research Organisation (EAAFRO), a branch of the then East African Community. In the same year, sorghum work at Ukiriguru in Tanzania was transferred to Serere by EAAFRO, and since then cultivars have been developed to cover the whole of East Africa. Germ plasm is received from and exchanged with several sources such as Ethiopia, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Semi-Arid Food Grains Research and Development (SAFGRAD), Texas A & M University, and other organizations actively engaged in sorghum research.

PROJECT OBJECTIVES

The ultimate objectives of sorghum research at Serere are to improve yield, quality, maturation period, plant height, and resistance to diseases, pests, Striga, and lodging.

Specifically, the objectives are to:

(1) Select high-yielding palatable sorghums with white or brown flinty grains that are resistant to leaf diseases and insect pests and have good weathering attributes.

(2) Select drought-escaping or drought-tolerant sorghum varieties for growing in the more difficult Karamoja and North Teso areas.

(3) Develop high-yielding short sorghum hybrids with good grain quality that are resistant to diseases and insect pests and have good weathering attributes.

(4) Screen for grain-mold resistance.

(5) Select varieties having a satisfactory level of resistance to shootfly, witchweed, weevils, and other insect pests.

(6) Continue to evaluate the performance and adaptability of improved sorghum varieties and hybrids screened from existing programs over a wide range of environments with the aim of identifying suitable varieties for release to farmers.

(7) Select for early seedling vigour, good seedling establishment, and better plant stands in the field.

(8) Select the most acceptable grain types consistent with the prevailing bird damage situation.

METHODOLOGY

At Serere, there are over 3000 entries in the world collection. These are grown each year for character evaluation and maintenance.

Records are kept of imported, collected, assembled, and locally bred varieties/lines. The entries with desirable characteristics are selected for inclusion in the breeding programs. A number of methods are used in the improvement efforts:

(1) Conversion methods for improving self-pollinating cereals have been adapted.

(2) Population improvement methods developed so successfully for maize are being applied to sorghum as well. In effect, the procedures adopted are: (a) In the development of high-yielding palatable sorghum with white or brown flinty grains, selection criteria include grain endosperm hardness and over 50% corneousness, larger sized panicles with medium to large seeds, and a good seed set. Activities include mass selection, selfing, and recombination. (b) Development of drought-escaping or drought-tolerant varieties for the semi-arid areas: Local Turkana sorghum selections and improved Serere varieties are being combined. Early-maturing derivatives are crossed with CK 60 to produce early-maturing sorghum hybrids. (c) Screening trials: A large number of genotypes that have been visually selected from segregated populations are being screened for yield and any other obvious agronomic or grain-quality weakness that may not have appeared in previous generations of visually selected genotypes. (d) Breeding high-yielding sorghum varieties that are resistant to weathering and grain-mold fungi: This program aims to identify grain mold causal agents and screen and identify resistant sources that are utilized through appropriate breeding procedures to combine grain-mold resistance, grain quality, and agronomic excellence.

(3) The testing of promising lines of sorghum is carried out throughout Uganda at Variety Trial Centres. These are 40 in number and are distributed within the three principal ecological zones distinguished by rainfall and altitude -- cool, wet highlands; moist Lake Basin zone; and semi-arid lowlands. These centres are managed by Variety Trial Observers under the Department of Agriculture extension service. The variety hybrid developed at Serere is sent for testing of its performance, stability, and adaptability to all of the centres. These centres have proven very useful in adaptability evaluations of particular varieties, e.g., it was found that the variety Serena takes about 105 days to mature in lowland areas but more than 120 days in high-altitude areas. Also, variety Dobbs Bora was found to be better suited to the wetter areas around Lake Victoria. A successful variety is recommended for release in a specified zone to the Variety Release Board. The board, if satisfied, releases the variety. Then, the Seed Multiplication Scheme multiplies the seed and makes it available to farmers through Cooperative Societies.

Although sorghum breeding has continued along similar lines for 30 years, the principal program improvements made recently have been the addition of agronomy and entomology objectives.

PLANT DISEASE ASPECTS OF SORGHUM IN UGANDA

The sorghum improvement project at Serere, although concentrating on breeding, considers sorghum diseases as one of the major criteria upon which to base selection. A survey of farmers' crops was conducted in Northern, Eastern, and Southern Uganda to assess the occurrence and distribution of sorghum diseases. The survey showed that diseases can be a limiting factor in the production of sorghum in Uganda. Varietal susceptibility can lead to up to 100% loss of the crop. Both foliar and inflorescence diseases occur. Generally, foliar diseases are more important on the local varieties, whereas grain molds are more important on the improved varieties.

Among the foliar diseases, anthracnose (Colletotrichum lindernuthianum) was rated as the most important, particularly in high-rainfall areas of Eastern and Southern Uganda. It was the most frequent and most intensive foliar disease on most sorghum varieties. In highly susceptible varieties, the disease occurred before flowering and intensified toward maturity. Often, in such varieties, the disease led to severe defoliation, the resultant effects of which were lengthening the maturation period, or incomplete filling of the grain, or both. In the less susceptible varieties, symptoms appeared after flowering and did not seem to affect grain development. Other diseases that were found to be important on local cultivars included gray leaf spot (Cercospora sorghi) and zonate leaf spot (Gloeocercospora sorghi). Interestingly, it was observed that on varieties with zonate leaf spot and gray leaf spot, anthracnose was absent.

In Northern Uganda, gray leaf spot was observed to be the most important foliar disease. However, the disease sets in when the plant is approaching maturity so, economically, it may not be very important. Sorghum downy mildew (Peronosclerospora sorghi) is another important disease. Early infections led to complete leaf shredding. In such cases, the plants did not head at all; they remained stunted and dried up prematurely. Later, infections led to the production of small heads and poor grain development.

This survey, therefore, revealed that three foliar diseases, anthracnose, downy mildew, and gray leaf spot, need immediate attention.

On the heads, grain molds are important. The infested grains develop fluffy-white or pinkish or black discolourations. Both types of discolourations may be present on the same head. Grain molds have become a major and widespread disease problem. The disease has been known to cause yield losses due to the failure of the grain to produce seed. Qualitatively, grain molds lower the market and nutritional value of the grain. The market value is lowered due to grain discolouration, whereas the nutritional value is lowered due to deterioration resulting from physical and chemical changes in the grain. The disease also causes loss in viability of the grain and reduction in seedling vigour. Infected seedlings that germinate often produce blighted seedlings.

Grain molds, therefore, are proving to be one of the major disease and research problems in the improvement of the sorghum crop. The infection is invariably more intensive on the improved light-coloured seed cultivars than on the local dark-coloured cultivars. It is postulated that these improved cultivars lack the built-in mold escape mechanism inherent in the local varieties (Williams and Rao 1978).

A number of methods, including the use of fungicides for the eradication of and protection against pathogens, and quarantines and seed certification for the exclusion of pathogens, have always provided very effective control of plant diseases. These methods, however, are expensive and sometimes require very precise operations by the farmer before any appreciable benefit can be achieved.

Hence, it is recognized at Serere that screening for crop genetic resistance is the one and probably only way of economically controlling the diseases affecting sorghum. A backcross program is planned to incorporate anthracnose and other leaf-disease resistance into the highly susceptible local varieties while still maintaining their good attributes. As for grain molds, heavy selection pressure must be exerted on much of the working material because most of the improved varieties are highly susceptible.

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SORGHUM IMPROVEMENT IN ZIMBABWE

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Sorghum (*Sorghum bicolor*) has been grown in Zimbabwe for the last century; however, little effort has been made to commercialize the crop until recently. Commercial sorghum production in Zimbabwe dates back to the early 1900s. The increasing demand for grain sorghum in brewing and stock-feed industries has necessitated serious agronomic research to identify high-yielding varieties. The research task was entrusted to the Department of Research in the Ministry of Agriculture. The research involved plant population, seeding rate, and date of planting trials. In addition, fertilizer levels by date of planting were also studied. During the early part of the 1950s, agronomic trials on pearl millet (*Pennisetum typhoides*) were initiated to establish optimum plant populations and row spacings. Some research results at Matopos showed that planting in early October, coupled with close spacing, yielded much better crops than planting in November (Matopos Research Station, Annual Report 1956/57). Cackett (1960) found that an interrow spacing of 45-60 cm gave maximum yields and kept interplant competition to a minimum.

Initial sorghum breeding started in the 1940s, when a number of materials introduced from the USA, South America, and East Africa were grown for observation and bulking. Due to improper record keeping and a rapid turnover of plant breeders, a large number of materials were mixed. This made it difficult for the incoming breeder to sort out pure lines. During the 1956/1957 season, an effort was made to sort out both sorghum and pearl millet materials. Out of a total of 300 original introductions and 87 selections of sorghum, only 250 lines were kept for further testing. In pearl millet, 115 selections were made but only 18 lines were kept for further improvement (Matopos Research Station, Annual Report 1956/57). A recurrent selection program was initiated in pearl millet breeding during the 1957/1958 season to improve the locally grown Tjolotjo bearded variety. Lack of reasonable yields and poor plant stands forced the program to be dropped.

The first phase of sorghum breeding suffered from a shortage of staff and reasonable materials. The second phase covered the 1968/1969 - 1979 period, when a new plant breeder was appointed. During this period, development of experimental hybrids using male sterile lines was initiated. Also, a recurrent selection program was started with Feterita and Red Swazi, with Framida as a donor parent. The aim was to combine the desirable head, stem, and seed characteristics of Framida with the early maturation and short plant stature of Feterita and Red Swazi (Matopos Research Station, Annual Report 1968/69). The third phase, which we are currently in, was developed from the second phase after having evaluated all the materials for yield potential and stability.

In pearl millet, the first phase was during the 1940s and 1950s, when the first introductions were made. It was followed by a recurrent selection program and then shelved. The second phase started when Dr Muchena made a survey of pearl millet production in the country. Several collections were then made. Materials from the USA and India were brought in. Initial hybrid development was undertaken as well as pedigree selection. The third phase started in 1979 and is an improvement on the initial program.

AREAS OF CROP PRODUCTION

Sorghum and pearl millet crops normally grow in semi-arid environments where other crops tend to fail. Ferguson (1951) mentioned that sorghum would do well over a wide range of soil types and climatic conditions; however, he cautioned that certain varieties have been bred for specific conditions. In Zimbabwe, however, sorghum and pearl millet are mainly grown in the drier areas where maize would not do well. In the past, the sorghum breeding program catered to commercial farmers only, i.e., large-scale farmers with large hectarage. With the advent of majority rule, however, the objectives have been changed to accommodate the large number of communal farmers, i.e., those who own 5-10 ha. The major areas of sorghum production are Matebeleland North and South, which contribute about half of the country's total production. Mashonaland Central ranks second with a total of 26 713 t, followed by Midlelands and Manicaland.

Department of Agriculture, Technical and Extension Services (AGRITEX) 1982/1983 production figures show that most pearl millet was produced from Matebeleland South, Mashonaland Central, and Matebeleland North, in that order. Some reasonable amounts also came from Manicaland and Masvingo Provinces. The most common sorghum varieties grown by communal farmers are the tall and late-maturing indigenous types. These include both red and pearly white grain, with or without compacted heads. Some improved varieties such as Red Swazi, Red Swazi "A," Feterita, and Framida are also grown. In addition, hybrids such as DC 99 and DC 75 are grown by those who can afford to purchase the seed.

In pearl millet, communal area farmers mainly grow the tall and late-maturing local varieties. Such varieties, however, are prone to bird damage because they mature after other crops have been harvested. A number of promising varieties are being tested to replace the locally grown material.

Normally, sorghum and pearl millet are grown with little or no inputs at all; however, the farmer grows them after groundnuts. This is to ensure that the nitrogen fixed by the groundnuts is utilized by the sorghum and pearl millet. Generally, sorghum and pearl millet are grown as monocrops; however, there are isolated cases where mixed cropping is practiced. A large number of communal farmers grow the two crops in rows to facilitate cultivation and harvesting. In the large commercial sector, all sorghum is planted and harvested by machine. These farmers normally use hybrid seed that gives profitable yields.

INSTITUTIONAL ORGANIZATION OF THE PROGRAM

The Crop Breeding Institute is organized in such a way that each crop is a separate discipline within the institute. The sorghum and pearl millet improvement program is composed of a sorghum breeder, a pearl millet breeder, a technician, and two agricultural assistants. An additional team, made up of a technician and two agricultural assistants, is being formulated as a result of the International Development Research Centre (IDRC) aid program. The two teams will operate jointly under the team leader, who is also the sorghum breeder. It is hoped that one team will concentrate much more on off-station trials and nurseries while based at Matopos Research Station, Bulawayo. The other team will be involved in the breeding of the two crops. The sorghum and pearl millet improvement program off-station trials, although planned by that program, have so far been carried out under the supervision of the Agronomy Institute staff. However, a suggestion has been tabled that the off-station trials should be the responsibility of the breeding team. The off-station variety trials are currently planted and managed by the Agronomy Institute, which is responsible for all agronomic research to improve sorghum and millet production practices and has an increasing workload due to farming systems research activities. Intermediate and advanced variety trials are sent to research stations all over the country, where agronomists supervise the planting of the trial as well as the collection of data during the season. At maturity, the agronomists harvest the crops and record the data. The record books are sent to the plant breeder for analysis. In addition to trials handled by the agronomy personnel, some small on-farm trials are coordinated by the agronomy staff in the communal areas with the help of extension workers in AGRITEX. There is a free flow of seed materials to other programs such as farming systems, plant protection, and agronomy.

PROGRAM OBJECTIVES

The objectives of the sorghum improvement program are to develop pearly white sorghum varieties that are suitable for making locally preferred food products, on the one hand, while continuing to develop high yielding and good quality red seeded sorghums for making opaque beer, on the other. The long-term objectives are to develop varieties that are drought tolerant, early maturing, medium in height, high yielding, and possess hard endosperm grain for long storage.

With respect to pearl millet, the objective is to develop high-yielding varieties that mature in about 100 days and have a medium plant height.

Most of the sorghum research effort was concentrated on red grain types suitable for making opaque beer. Although this is still one of the major objectives, a similar effort is being placed on the development of pearly white grain sorghum that is suitable for food products. Severe drought has recently affected the region for two successive seasons. This emphasizes the need to develop drought-tolerant varieties for the marginal rainfall areas of Zimbabwe.

Because hybrid seed would be expensive for most of the communal farmers, the program aims to develop several open-pollinated varieties, the seed of which farmers would be able to purchase at a cheaper price. However, hybrid development is still a major part of the sorghum-breeding program. The communal farmers normally experience low plant stands that result in poor yields. However, it has been observed that the compensatory effect of the tillering ability of some varieties contributes significantly to high yields when the population is low. Therefore, nontillering varieties may not be desirable for farmers who experience such low populations.

The breeding strategies for pearl millet are, to a certain extent, similar to those for sorghum. In sorghum breeding, the major emphasis is on hybrid development, coupled with high-yielding open-pollinated varieties. In pearl millet, open-pollinated varieties and populations are much more important than hybrids. Pearl millet is a protogynous crop; consequently, hybrids are more susceptible to ergot disease than varieties. This results from the competition between pearl millet pollen grains and ergot inoculum on the stigmas. The local pearl millet varieties are tall and late maturing. Thus, there is a great need to develop early-maturing varieties with high yield potential and that are of short to medium height. This would be beneficial in the management of the crop. These breeding objectives can be achieved by making use of the backcross method to transfer the desired characteristics. Although a large number of communal farmers grow sorghum and pearl millet, various plant populations are being used because there is no established population recommendation for the two crops. Therefore, research in this direction is needed to establish optimum populations for both crops in the different ecological zones of the country.

EVALUATION METHODS

Introduced materials are normally grown in an observation nursery where they are evaluated for disease reaction, insect pest tolerance, and adaptability. Information is collected on a number of characteristics such as plant height, days to flower, and days to physiological maturity. This is the basic information used in the selection of lines or populations for further development into elite lines. In the case of improved varieties, hybrids, and elite lines, preliminary trials are established at two or three locations where they are evaluated for good agronomic traits. These include high grain-yield potential, medium plant height, days to flower, minimal lodging, and about 100 days to attain physiological maturity. Materials selected from such trials go on to intermediate and then advanced variety trials. At this stage, multilocational testing at sites located in the five different ecological zones of the country helps to identify varieties adapted to specific areas of the country. Further evaluation is carried out at harvest, at which time materials are assessed for lodging and the ability to remain green at physiological maturity, a feature that allows full grain development.

In most cases, trials are planted and monitored by the sorghum and pearl millet team. However, the daily management is carried out by agronomy personnel. There are isolated cases where it is impracticable for the sorghum and pearl millet team to physically plant at certain stations. In such cases, the seed would be sent to the agronomy staff at a given station who would then plant and manage the trial until it is harvested. Normally, the breeding team would visit the trials once or twice during the season to assess the materials being tested. It has been a common practice to include a standard variety that is locally grown to assess the potential value of newly developed varieties.

ON-FARM OR COMMUNAL-AREA TRIALS

It has been a common practice for the sorghum and pearl millet program to give seed to the Agronomy Institute for on-farm trials. The agronomists set up the trials and make occasional visits, whereas the AGRITEX personnel make regular visits to the trials.

During the season, field days are organized by both Agronomy Institute and AGRITEX personnel, to which breeders are invited to see the trials. In some cases, the breeders send the seed directly to communal-area farmers and AGRITEX staff as a way of demonstrating and exposing available materials to the farmers. In this case, communication between the breeders and communal farmers or AGRITEX staff is direct.

The program is limited in its facilities. As a result, food-quality tests are minimal. In the past, quality tests on pearl millet were conducted to assess the taste, colour preference, and palatability of the pearl millet thick porridge (sadza).

The sorghum and pearl millet program has so far employed individual and across-site analysis. This has proven to be sufficient to determine the stability of varieties within defined agroecological zones.

SUMMARY OF METHODOLOGICAL APPROACHES

In the past, the sorghum improvement program used to serve the interests of the large-scale commercial farming sector only. However, the program has now been extended to include the pearl millet improvement program as well as the communal farmers to develop improved varieties for both sectors. Both red seed grain sorghum for brewing opaque beer and pearly white edible grain sorghum are being grown in Zimbabwe by commercial and communal farmers respectively. However, no effort has been placed on the improvement of pearly white grain sorghum, which is used by the majority of the population to prepare sadza. In view of this, breeding efforts are now being directed toward the development of new open-pollinated varieties and hybrids of pearly white grain sorghum. Because sorghum is a relatively drought-resistant crop, it is hoped that food shortages can be offset by growing the crop in the marginal rainfall areas that are unsuitable for maize production.

Thus, the most interesting feature of the program is the emphasis on the development of pearly white grain sorghum that is suitable for food products. At the same time, work on red grain types is increasing.

The pearl millet program is now putting more effort toward the development of open-pollinated varieties and populations because they are less susceptible to ergot than hybrids. With regard to diseases and insect pests, there is strong cooperation between the breeders and research officers in the Plant Protection Research Institute.

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SORGHUM IMPROVEMENT IN SOMALIA

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Sorghum is the major crop grown in Somalia, with about 57% of the cropped land (517 000 ha) now under sorghum. The crop is grown almost everywhere and under rainfed conditions, as in most of the semi-arid areas. In the area between the Juba and Shebelli rivers, maize cultivation has increased in popularity over sorghum because it is easier to cultivate, has a higher yield, and is less affected by grain-eating birds such as Quelea quelea.

Sorghum will continue to be the most important crop in Somalia for the following reasons: it is the most promising and adaptable crop in the semi-arid climate, where the limited rainfall received is highly variable and generally unreliable (mean total rainfall in the area of highest potential for sorghum reaches only 350 mm per crop season); it is well accepted as the main staple of the people; research carried out in Somalia and elsewhere has shown that new sorghum types or gradual improvement of existing varieties will probably produce types that have grain qualities close to those of maize under similar semi-arid climatic conditions; and because Somalia will continue, for a long time to come, to be a livestock-producing economy, sorghum grain and stalks will be of major importance as livestock feed.

Sorghum varieties grown in Somalia include: late-maturing varieties that take 6 months to mature, commonly grown in the highland regions of the north and northwest that have a single growing season each year; and early-maturing varieties that reach maturity in 3-4 months, grown in the southern areas of the country and having two distinct annual cropping seasons. These are low-yielding varieties, naturally selected by the moisture conditions in the field over many generations. The selection criterion is stable yield under unfavourable moisture conditions. The early-maturing varieties are well accepted as being palatable and their grain stores well.

CULTIVATION METHODS

Apart from a few farmers who use tractors for land preparation, most farmers practice traditional methods of farming. The "yambo," a small hoe, is the principal instrument that Somali farmers have at their disposal. The use of oxen is more widely spread in the northern and northwestern regions than in the southern regions. Sorghum, which is used mainly for its grain and fodder, is grown twice a year in the southern regions and only once a year in the northern regions. Sowing is accomplished either by hoeing and broadcasting or by dropping the seed in the furrow behind the plow when animal-drawn implements are used. Through continuous work and without excessive effort, the Somali farmers keep their fields in good condition all year round. Harvesting is accomplished by cutting the panicles, which are stored in an underground pit, or threshing and winnowing, if the produce is to be used quickly. The stalks may be grazed by the animals in the field or cut and conserved as forage for the animals during the dry seasons.

UTILIZATION OF SORGHUM GRAIN

Sorghum is used in different forms, either before or after fermentation. Some of the sorghum preparations widely consumed in Somalia include: soor -- a kind of thick porridge prepared by adding sorghum flour to boiling water and continually stirring until a thick jell is formed; mushariyo -- similar to soor but not as thick and made with oil, sugar, and pepper; anjero -- a leavened, round, flat bread made from sorghum to which some wheat flour is added; mufo -- round flat bread plus sour unfermented sorghum baked in a special oven called "tinaar"; kibis -- sometimes called "mufo-daawo," made from fermented sorghum to which some wheat flour is added and then baked in a pan rubbed with some ghee or any vegetable oil; and anbuulo -- made by putting the sorghum grains alone or with cowpea or mung bean in water and boiling until no water remains.

SORGHUM RESEARCH

Agricultural research in Somalia is the responsibility of the Agricultural Research Institute (ARI), established by the Ministry of Agriculture in 1975. The institute has its headquarters in Mogadishu. Its main research station, the Central Agricultural Research Station (CARS) is located at Afgoi, about 30 km west of Mogadishu. There are three substations to support CARS activities, enabling the testing of the technology and crop varieties under development for wider applicability and adaptability in the major agroecological zones. The Jilib substation, near Kismayo in the middle of Juba Region, is chiefly concerned with irrigated agriculture. The Bonka substation, in Baidoa, Bay Region, is in the area with the best potential for sorghum production. It is concerned with rainfed production over a wide area of the southern uplands region and the upper plains land of adjoining regions and is the national coordinating station for sorghum improvement. The arid to semi-arid area in the northwestern region is served by a substation at Aburein, near Hargheisa.

The Agricultural Research Institute is assisted by a United Nations Development Programme/Food and Agriculture Organization of the United Nations (UNDP/FAO) project that aims at strengthening national research capability in soils, agronomy, maize breeding, and farming systems research. The substations are, as yet, inadequately developed, but they are receiving increasing attention. There is a need for more staff at these stations, particularly in the field of breeding.

NATIONAL SORGHUM IMPROVEMENT PROGRAM

The National Sorghum Improvement Program of the ARI has been reorganized based on clearer objectives and with the cooperation of different agencies or development projects, including the Bay Region Agricultural Development Project (BRADP) and Northwest Region Agricultural Development Project (NWRADP), with the support of the International Development Research Centre (IDRC). The program's main objective is promoting the production of sorghum for food under rain-fed conditions in different agroecological zones of Somalia through the provision of improved varieties with good yielding potential, excellent grain quality, desirable agronomic characteristics, and resistance to insects and diseases.

For these improved varieties to be accepted by the traditional sorghum growers and consumers in Somalia, they must have excellent grain quality with prolonged grain storage life, as found in indigenous varieties. To achieve these objectives, the program has several components.

Screening and Selection of Varieties Using Local and Exotic Germ Plasm

Local cultivars, partially collected in 1979, and varieties received from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and from other sorghum improvement projects are evaluated for their adaptability, yield, and quality of grain under Somali conditions. The selected varieties are evaluated further before they are released or crossed with promising local lines to improve the local varieties. Selection of materials derived from crosses is expected to give rise to promising lines for further testing and eventual release.

The major criteria for selection include: early maturation, to escape drought during the short, low-rainfall periods and minimize bird damage; medium plant height, to reduce lodging; high yield; resistance to disease, especially smut; resistance to pests, especially shootfly and stalk borers; grower and consumer acceptability; resistance to bird damage; and better grain storage ability.

Breeding

The breeding program, initiated as part of the varietal development program, aims at incorporating the desirable characteristics of the most promising introduced varieties into the best local varieties while maintaining the superior drought and pest tolerance demonstrated by the latter varieties in on-farm tests. The actual hybridization is carried out at Bonka, but selection is conducted in different locations.

The work includes breeding for resistance to drought and stem borers. At present, we are in the preliminary stages of screening for resistant or tolerant varieties.

Sorghum Agronomy

Research conducted by ARI has shown that improved cultural practices, such as timely planting, weeding, pest and disease control, soil moisture conservation, and bird control, can more than triple sorghum yields. Hence, there is a need for more research and extension work in the various agroecological zones.

Date of Planting

Usually, the farmers wait for the first rains to soften the soil before starting to sow. The time of planting is very important because the rainy period is short. Studies on planting dates will help growers determine the appropriate time to sow to maximize use of available moisture. Localized studies have shown that timely planting can increase yields by 50-80%.

Plant Population

Plant populations observed in farmers' fields are much lower than optimum. Preliminary studies have shown that populations of 30 000-50 000 plants/ha produce higher yields. The farmers' practice of sowing 4-6 seeds/hill and not thinning is being discouraged. A better distribution of the plant population over the field is expected to increase yields by making more efficient use of available moisture.

Moisture Conservation

A traditional method of accumulating moisture in the soil is through the use of basins and bunds. Basins are made on sloping land and their size varies from 2 m x 2 m to 25 m x 25 m, depending on the slope. Bunds are built along parallel lines, 20-30 m apart. Tests conducted in bunds and on open land have shown significant differences in favour of bunds.

Crop Protection

The most important disease affecting sorghum is smut. Studies have shown that up to 60% reduction in yield can be attributed to attacks of smut. Research is attempting to identify the best and safest seed treatment chemicals to prevent or reduce losses due to smut until such time as varieties with genetic resistance to smut are available.

Anthracnose and leaf blight may cause some damage but their economic importance is very low. The most important insects causing extensive damage are stem borers and shootflies. For the time being, the only treatment available is through the use of diazinon in granular form. Research is also attempting to identify varieties that are resistant or tolerant to these pests. The work on disease and insect pests is being carried out in cooperation with such major centres as ICRISAT and Texas A & M University.

Protection from birds is another problem under study. The Quelea is the most important among the birds feeding on sorghum grain. The Quelea control program of FAO is trying to limit the population of these birds over the Eastern African Region.

ON-FARM RESEARCH

On-farm research in a farming systems context is a new approach to research in Somalia. Systematic work and technology testing under actual farm conditions, refining of research findings into recommendations, and economic evaluation of recommendations began in October 1982 with the establishment of a farming systems and economic research section at the Central Agricultural Research Station, Afgoi.

The research activities of this section comprise two components:

The first involves the selection of two representative benchmark villages, in both the irrigated and rainfed areas. A farm survey to analyze the present farming conditions of small farmers has been conducted with reference to resource endowment and allocations, farm practices, and farm management analysis. During the first season, emphasis was placed on labour management and the farmers' attitude toward adoption of new technology. A representative sample of 15 farmers in each village was used and information was collected through multivisit interviews and group discussions, accompanied by regular field visits and direct observations of farm operations. Crucial information has been cross-checked in other locations.

The criteria used for the selection of the villages were that they should be typical of the main maize- and sorghum-producing areas, respectively, and that activities of other institutions, such as extension and irrigation projects, should be limited in order to study prevailing traditional systems. It must be stressed that the study is neither statistically valid nor applicable countrywide. It is intended as an in-depth case study.

The second component involved on-farm trials in the two selected villages to test research recommendations. The trials are managed entirely by the farmers, using their own cultural practices. The selected farmers should not cultivate more than 5 ha, but the main criterion is their willingness to participate in the experiments. During the 1983 season, 38 trials were planted by the farmers to test new maize and sorghum varieties. A new cowpea variety was planted as a pure crop and groundnut was planted as an introduction into the cropping system. In addition, chemical stalk borer control in maize and sorghum was evaluated. Finally, some hand tools for weeding and maize shellers were tested. Observations on the trials are made regularly but emphasis was placed on the mutual training of researchers and farmers. The trials will be evaluated both in agronomic and economic terms.

To establish a continuous flow of information from research through extension to the farmers, a cooperative on-farm program between research and extension workers has been initiated for further on-farm testing of research findings that have already reached the stage of recommendation.

TOWARD A MAIZE PROGRAM RESPONSIVE TO BURUNDI FARMERS

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B.P. 795, Bujumbura, Burundi

Averaging 155 persons/km^2, Burundi is one of the most densely populated countries in Africa, but population densities range from 50-300 persons/km^2 (Maton 1983a). Over 90% of the populace is rural, villages, as such, being nonexistent (Mertens 1981). The amount of arable land per inhabitant varies considerably, but in the region of Mugamba, a high-elevation area where maize is very important, the average area cultivated is 1.67 ha/homestead and 0.27 ha/person (Maton 1983b). The gross national product per capita is estimated at US$180 annually (World Bank 1981). This low income combined with high population density results in intensive exploitation of the land. Most regions in the country have at least two cropping seasons per year on any given plot.

Maize is the second most important crop in Burundi, after common beans, in terms of area cultivated. The Department of Agronomy estimates that 260 000 ha are cultivated in maize, with an average yield of 1.5 t/ha. Although the crop is grown throughout the country, its importance varies considerably from one region to another. In the highland areas (1700-2200 m), maize is the staple food and, consequently, occupies a large land area -- often more than 50% of the total land under cultivation (ISABU 1979). However, it is almost always interplanted with beans, peas (Pisam sativum), or other crops. Maize becomes less important at lower elevations (800-1200 m), where cassava becomes more important in the diet, and maize plantings become small or very low density in intercropping associations.

Over most of the country, there are two maize crops: rainy-season upland and dry-season bottomland. The former is by far the most important and is planted in late September or early October after the first rains signal the end of the principal dry season. Dry-season bottomland maize, planted in July and August in moist valleys, accounts for only a small portion of total maize production. However, the harvest from these plantings is quite important. The bottomland crop is harvested in December or January and comes at a time of annual food shortages, when the current upland crop is not yet ready and the previous year's harvest has been consumed.

BURUNDI MAIZE PROGRAM

The Burundi maize program is part of the Food Crops Division of the Institut des Sciences Agronomiques du Burundi (ISABU). ISABU is the main research arm of the Ministry of Agriculture and Animal Husbandry and is composed of four principal research stations and numerous research centres. The headquarters for the program are located at the main ISABU research station in Kisozi. The current professional staff includes one expatriate adviser (IDRC), two university-level agronomists, two technical school-level agronomists, and an administrative assistant. The adviser's expertise is in plant pathology and breeding. The two university agronomists specialize in soil science and rural sociology. One of these agronomists will begin a Master's program in plant breeding in 1983 in Canada.

The broad objectives of the program may be summarized as follows:

(1) To develop maize varieties that produce greater yields than the local material presently used and satisfy quality and cropping-cycle requirements within local soil, pest, and pathogen constraints.

(2) To orient the selection process to be responsive to the role of maize in the traditional mixed-cropping system.

(3) To develop, and include as a routine step in the development of new varieties, a system of on-farm evaluation of promising material.

(4) To improve and encourage cooperative research with other ongoing programs in ISABU.

The first objective stems from the observation that there is substantial room for improvement over local varieties. Because maize is not a native crop, there is probably considerable potential for growing exotic material successfully. In the medium and low elevations, some Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) experimental varieties have shown promising results. Although exotic material tested in high-elevation environments has not shown much promise as yet, selections from good local material and, perhaps, subsequent crosses should enable rapid progress to be made.

The other objectives stem from observations that most of the past research on maize has been conducted on experimental stations under conditions that are far removed from those found in farmers' fields (e.g., monoculture with mineral fertilizers, which are almost unavailable in this land-locked country). Little attention has been given to the role of maize in the whole cropping system of an area. Although initial introduction, selection, and improvement must be conducted at the research station, the inclusion of on-farm trials as part of the evaluation process should enable us to identify apparently high-yielding material that is unacceptable to farmers before it is released. Cooperation with other ISABU programs (e.g., legumes) will facilitate evaluation of different improved components of a cropping system.

METHODOLOGY

Selection Methods

In general, we work with a system of half-sib family selection on population and varietal crosses. In the case of a large population, the best families may be chosen for a diallel cross to form a variety or a bulk of families may be used. At this time, we have no plans for the creation of inbred lines and hybrids due to a shortage of resources and difficulties in improving infrastructural support in such a mountainous country.

Criteria

Growth Cycles

Among the most important criteria for high-elevation maize is the length of the growth cycle. Any variety that is too late (>190 days) cannot be considered, regardless of yield. Following our multilocational yield trials with the usual second-season crop (peas), we found that late varieties had a negative impact on the second crop. In the subsistence agriculture found in Burundi, coupled with the high population density and intensive land use, it is apparent that farmers work to optimize output per field per year. In a less densely populated area with more market-oriented production, it is possible, or even likely, that farmers would seek to maximize maize production and prefer a long-season variety. In the middle and lower elevations, even the latest varieties permit a second crop, so the growth cycle is not as important in these areas.

Yield

Conversations with farmers have revealed mixed feelings with regard to the importance of yield versus grain quality. At present, our impression is that substantially higher yield will take precedence over most quality considerations. Although detailed field observations are made on pest and disease levels, results of our trials indicate that yield integrates these factors with tolerance of soil and climatic factors to give the overall adaptability or "rusticity" of a variety.

Quality and Storage

The most commonly stated quality requirements are grain size, hardness, and colour. Because most maize for flour production is ground by hand, varieties with large floury (soft) kernels are desired. Yellow kernel colour is associated in local varieties with small flinty kernels and low yield and is, therefore, not desirable. Storage loss of maize is a primary complaint of Burundi farmers and may very well nullify any increase in production. Thus, varieties that show differential susceptibility to field infestation by storage pests are immediately discarded. Likewise, in population improvement, selection for good tip coverage of ears is a high priority.

EVALUATION

On-Station Trials

A certain portion of maize improvement and development must continue to be conducted on research stations. However, we are designing our on-station research to make the selection process as realistic as possible as well as to enable us to test certain hypotheses developed from our farm visits and on-farm trials (e.g., selecting under low input conditions and a mixed-cropping system). Recognizing that maize is but one part of a subsistence system, we evaluate the varieties in terms of yield/hectare/year, including the major component of a typical rotation and a full year's cropping in our evaluation fields. This has suggested to us the reason why a recommended high-yielding late variety of maize has proven unacceptable to farmers -- it does not permit a productive second crop.

Introduction Trials

The majority of material presently received by the program is in the form of CIMMYT experimental varieties for various ecological zones. These are evaluated according to CIMMYT specifications. Varieties with an appropriate growing season and yields exceeding local or released materials by at least 20% are retained. Evaluations are conducted on research stations and, as with all evaluations in the program, receive only cattle manure, if anything, as a soil amendment. Other introduction trials are evaluated under a mixed-cropping sequence immediately.

Multilocational Trials

Those varieties retained are placed in multienvironmental trials at three or four sites with other promising material and local and released varieties. Beginning in 1983, these trials are to be interplanted with a local cultivar of beans. Maize varieties are evaluated based on whole-plot yield and overall performance of both crops to evaluate for compatibility. Results are analyzed using multienvironmental analyses of variance, with particular emphasis being placed on varieties showing little interaction with sites (i.e., broadly adapted).

On-Farm Evaluation

On-farm trials now constitute the pivotal point of our evaluation. Introduction and multilocational trials are intended to identify material that has no hope of being useful as well as material that may be of value. No decision for release can be made on the basis of the first two steps regardless of the number of years of evaluation.

In 1982, we set up preliminary trials with farmers at one site to identify potential difficulties in on-farm work. At planting time, we contacted several farmers near the home of one of our agronomists. Our plan was to compare the local maize variety with the released variety recommended for the region and to compare station methods (monoculture, in rows) with the local planting practice (simultaneous planting of maize/bean with traditional spacing) followed by the farmer. Thus, there were four treatments: local variety and released variety each planted according to experimental station methods and each planted according to the local practices. The farmers planted the "traditional" plots and we planted "station" plots. Each treatment was only represented once on each of the farms.

As we were preparing seed with the farmers, it became clear that good quality local seed was scarce because planting was well under way. This was borne out by the very poor stand of the local material planted at a known density. As the season progressed, it became obvious that our trials were on some of the farmers' worst fields. One field was so poor that there was essentially no yield from any treatment. We also found that our plot markers were often displaced. Toward harvest, one farmer harvested all the local variety early -- believing that we were only interested in the performance of the released variety.

Several lessons were learned from these initial on-farm trials:

(1) Farmers should be selected well in advance of the growing season so that the researcher can become acquainted with the farmer

and clearly explain the objectives and select a field that is relatively homogenous and not extremely fertile or infertile (this can be accomplished by observing the current crop). During the first visit, contact should be made with local government officials and extension agronomists, who usually will assist in farmer selection. Each farmer should be visited at least two or three times before planting begins.

(2) We should supply the experimental variety seed, but the farmers should plant all trials in their usual manner as well as supply all the labour and seed for local varieties and selected cropping mixtures. This should help ensure that the farmer will take an active interest in the trial and cooperate accordingly. Most importantly, we can be more confident that the conditions of our trials will approach those of a "typical" farm.

(3) Plot sizes should be kept small (<300 m^2) so that they can fit within a farmer's field. Also, they would require less labour. Plots should be marked with perennial plants (e.g., cassava or Colocasia) with cycles longer than maize to ensure that they will remain undisturbed. Farmers tend to leave all crops in place regardless of what has been planted.

(4) Planting must be done at the same time as other plantings in the area, as results will be more reliable. It is then more likely that the farmer-supplied seed will be of reasonable quality than if plantings are done later than normal for the area. This will also permit comparisons to be made within the experimental field as well as, informally, with neighbouring fields.

(5) Farmers do not seem to mind contributing land if they are assured that they can keep all of the harvest and that the land will not revert to the government (ISABU) permanently. We have also found that good rapport is established quickly if we bring an instant colour-photo camera to the field and give the farmer and his family a few pictures of themselves. This also helps overcome farmer resistance to photographing routine fieldwork.

Because the on-farm aspect of our maize program is still in the early implementation and development period, only general plans can be outlined. For the time being, the country is divided into two maize producing zones -- middle/low and high elevations. In 1983, we have contacted about 30 farmers at five well-distributed sites over the middle/low elevation zone, for which we believe we have potentially good material. The three new promising varieties will be compared with the local material and a released variety each year. We expect that a minimum of 2 years will be required to demonstrate that a promising variety merits release.

Our approach to on-farm trials for varietal evaluation is not, strictly speaking, a "farming systems research (FSR)" approach. We have decided to accept the present system as a given and a not particularly well understood one and to force our "improved" material to fit within its constraints. Thus, rather than study a particular system with the purpose of understanding it and with the ultimate objective of providing a package of improvements, we are trying to work with only one component within the major constraints (cycle, soil, pests, and pathogens) and observe how the material is accepted, i.e., how our new material functions within the present system. We leave it to the farmer to make whatever adjustments are deemed appropriate. We believe that FSR is appropriate and valuable to our program; however, our personnel constraints are such that we cannot undertake the large effort necessary to implement a FSR program. What we can do is to try to have as much contact as possible with farmers in their fields to remain sensitive to their needs and the requirements of their systems. It is likely that ISABU will be beginning a FSR program within the next 2 years and we plan to cooperate very closely with this program.

MAIZE STREAK DISEASE

In high-elevation bottomland maize culture, maize streak disease (MSD) has become a serious problem within the last few years. The program is currently evaluating International Institute of Tropical Agriculture (IITA) streak resistant (SR) material. These materials are being planted in farmers' fields in areas with a history of high MSD levels. In addition, we are developing the facilities and methodology to conduct controlled inoculations to determine if SR varieties hold up under our conditions.

SUMMARY

The Burundi maize program is in a state of rapid change. The major emphasis in its reorganization has been to take into account the constraints and demands of local traditional maize culture. This is being achieved by duplicating on the experiment station, as much as possible, the conditions found on the farm. This includes no longer using mineral fertilizer or phytosanitary products, as well as evaluating material under mixed-cropping systems. The most fundamental change, however, is the inclusion of on-farm trials with active farmer participation as an integral and routine part of the selection and evaluation process. It has become apparent, however, that research must continue to be conducted on the experiment station (e.g., MSD evaluation and preliminary screening of crosses and introduced varieties). The program is working toward an optimum balance between essential on-station and on-farm research.

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GRAIN LEGUMES AND OILSEEDS

REVIVING GROUNDNUT PRODUCTION IN MOZAMBIQUE

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Groundnuts are extensively grown in Mozambique as a food as well as a cash crop. They are produced mainly by small-scale farmers on small plots of land. The agricultural surveys conducted annually from 1961-1970 placed groundnuts, in 1970, as the fifth most important crop in the country, occupying 9% (254 000 ha) of the total area under cultivation. The surveys also showed that 99% of the total area under groundnuts was cultivated by small-scale farmers (Missão de inquérito agricola de Moçambique 1970). Estimates in 1980 showed that 5% of the cultivated area was under groundnuts and the production was 90 000 t, giving an average yield of 450 kg/ha. This shows that, within 10 years, the area under groundnuts was reduced by half. This progressive decrease in groundnut production is associated with several limiting factors, especially droughts and seed shortages, so that today both the area under groundnuts and yields are severely reduced. Some areas that used to grow groundnuts have ceased to produce the crop. This is causing great concern both to the government and the public, so much so that a concerted effort is now being made to revive the production of groundnuts.

Working within the national strategy for increasing food production, the Groundnut Improvement Project started a modest research program in 1976, concentrating mainly on germ-plasm collection, multiplication, maintenance, and evaluation. The work of the project became more effective and gained momentum when the International Development Research Centre (IDRC) started giving financial support to groundnut research in 1980, making it possible for the project to work on other important aspects of groundnut research and production. In addition to research, the project is involved in training national scientists, field assistants, and labourers. To transfer its research findings to the farmers, extension is also becoming an integral part of the activities of the project. In this paper, an attempt will be made to give an overall picture of groundnut production and research in Mozambique and the role the project is playing in reviving groundnut production.

PRODUCTION AND YIELD

The major groundnut-growing areas in Mozambique are located in the provinces of Nampula, Zambézia, and Cabo Delgado in the north and Inhambane, Gaza, and Maputo in the south. Figure 1 shows that the

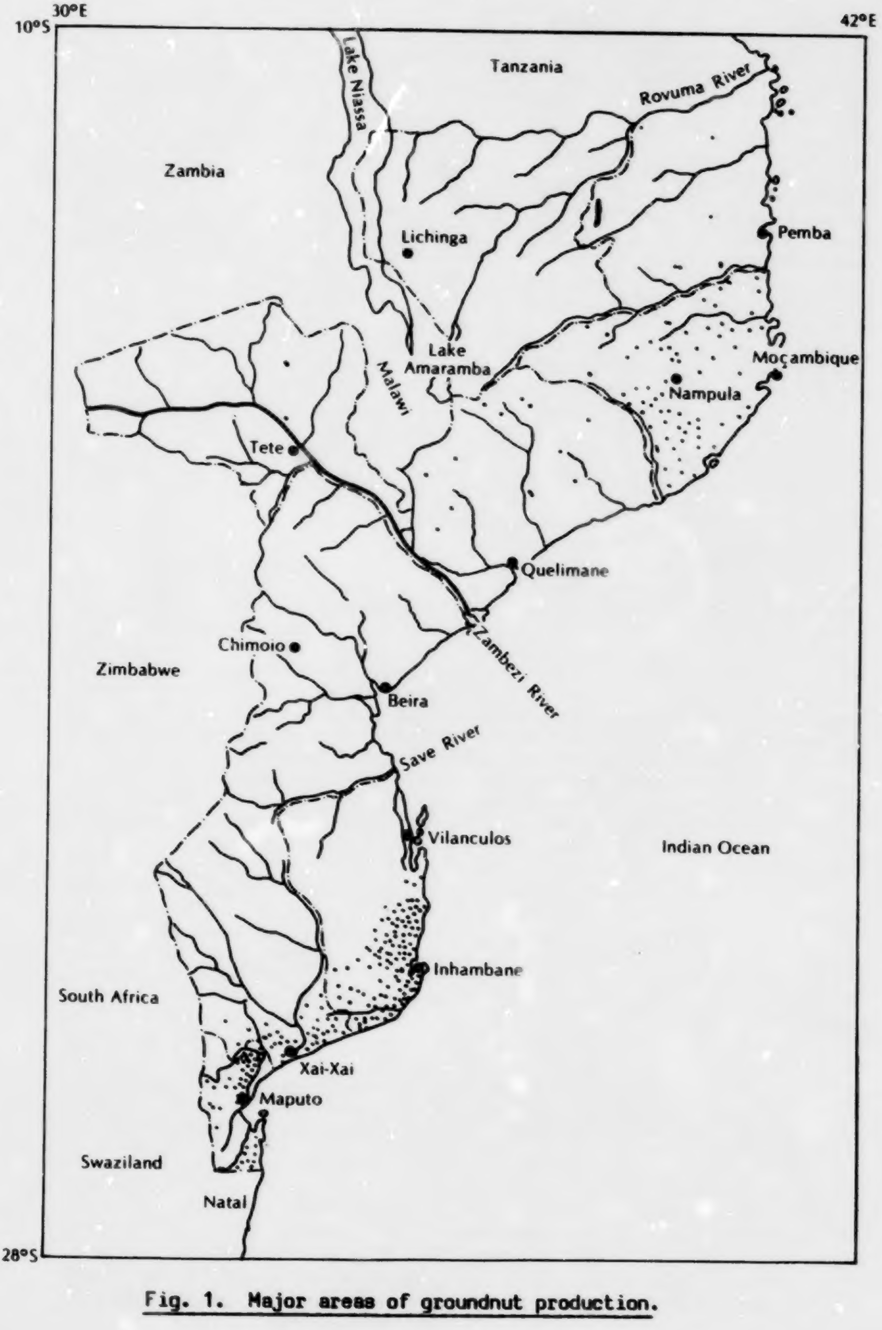

Fig. 1. Major areas of groundnut production.

coastal zone of Mozambique produces the bulk of the crop. It is also in this zone that the population density is the highest. It would appear that the demographic distribution and socioeconomic structure of the regions of the country influence, to a large extent, the production of groundnuts.

Traditional farming, involving very little investment, is practiced by all small-scale farmers in Mozambique. They form the largest group of farmers and it is this sector of agriculture that has been the most involved in groundnut production, both before and after independence. In traditional systems of farming, shifting cultivation (where land is available) and intercropping are generally practiced. Groundnuts are almost invariably intercropped with other crops, cassava and maize being the most popular. At present, there are no groundnut varieties recommended for use by the farmers, who grow landraces and keep part of their produce as seed for the next season. In the north, where the potential for groundnut production in terms of suitable soils and agroclimatic conditions is very high, the crop is grown mainly for cash as an oilseed crop and only small quantities are consumed as food. As such, there is a tendency for the farmers to give groundnuts second-class treatment in relation to the main staples of sorghum and cassava. Even so, the north is still the major producer of groundnuts.

Groundnuts are grown in the southern region both as a pulse food crop and for domestic cooking oil. They constitute one of the most important staples and are consumed, whenever available, daily in one form or another. However, the potential for groundnut production, as well as for other crops, is not as high as in the north due to the erratic rainfall pattern that can result in drought or flooding. In general, moisture loss due to evapotranspiration amounts to twice the total rainfall received (Carvalho 1969). Also, the soils where groundnuts are grown are predominantly sandy and poor in mineral nutrients and organic matter. Soil exhaustion due to continuous cropping is evident in many areas. Thus, although groundnut hectarage in the south is high, the yield per hectare is lower than in the north. Groundnuts are traditionally not grown in the central region, although the potential to do so exists.

In recent years, groundnut production in the south has been greatly reduced due to a lack of seed for planting. The scarcity of seed has been caused by consecutive droughts that, in 1982, culminated in one of the worst droughts in over 50 years, resulting in complete crop losses in some districts. In trying to beat the drought, farmers planted whenever it rained; but in all cases the crops dried up and, therefore, the farmers lost what little seed they had kept. Food shortages have been serious and farmers have been forced to eat their seed reserves. Thus, even if the rainfall should return to normal again, the farmers have practically no seed to plant and, therefore, no groundnuts to produce. Unless measures are taken to supply farmers with seed, groundnut shortages in the south will continue to be a serious problem.

Local Varieties

In the north, where the rainy season is prolonged, farmers grow mainly long-season populations of the Virginia type, comprising both runner and bunch types. These are more suitable for that agroecological zone than the short-season populations because the former are dormant whereas the latter are not. Short-season populations of the Spanish type are also grown, mixed with the Virginia types or separately. The mixture of long- and short-season groundnuts causes difficulties and loss in yield at harvest because harvesting the earlier Spanish type causes damage to the long-season types; if the short-season types are not harvested once mature, they start germinating in the field. The more common practice is to grow these two types of groundnuts separately, which permits the farmers to grow two crops per year of the early-maturing type.

In the south, the duration of the rainfall is short and intermittent and short-season landraces are normally grown. The most popular populations grown by the farmers are Bebiano Branco and Bebiano Encarnado, characterized by cream to light-brown seeds and red seeds respectively. They are both short-season erect types and mature at the same time. At planting, farmers mix red and cream seeds in varying proportions depending on their liking. The preference is for a higher proportion of Bebiano Encarnado because this gives better taste to food than Bebiano Branco. However, according to their observations, Bebiano Encarnado is more susceptible to drought and lower yielding than Bebiano Branco. Variety trials show that Bebiano Branco yields better than Bebiano Encarnado (Table 1). The project is applying mass- and single-plant selection methods to improve this population and to recommend the improved version for immediate use by farmers. The project has also recommended that only short-season varieties and populations be developed for the south and long-season varieties and populations in the north, although short-season varieties can also be grown in the north. Research results indicate that the yield of long-season varieties in the south is very low compared with their performance in the north, where short-season varieties also produce quite high yields (Tables 1-3). At the present level of traditional farming in Mozambique, population improvement using mass selection or the modified pedigree method of selection using single seed descent (SSD) and the development of multiline varieties appears to be in line with the farmers' needs. Such varieties will be more easily accepted by the farmer and their purity maintained than varieties originating from a single pure line, which will be blended by farmers to satisfy their needs. The farmers are aware of the genetic variability in the populations that they grow. They recognize various genotypes with respect to seed colour, plant habit, and maturity. At shelling, various seed types are separated according to size and colour; but at sowing the population is deliberately reconstituted in definite proportions according to the farmer's liking, with an awareness of the fact that such a blend provides security against disease and drought and, at the same time, satisfies food preferences. Varietal purity is not of concern to the farmer. Therefore, breeding methods should aim at developing varieties with a high frequency of genes for yield without impoverishing the genetic variability in the variety. Multiline varieties composed of superior lines tested for disease and drought resistance, quality, and yield might be the answer in Mozambique. Multiline varieties composed of agronomically similar but genetically dissimilar pure lines have been proposed for self-pollinated crops (Browning and Frey 1969; Frey et al. 1971; Schilling et al. 1983). Some varieties developed through mass selection are being evaluated together with the others. Improved populations of Bebiano Branco will be tested in farmers' fields in "on-farm experiments" that have already been initiated.

Table 1. Yield of shelled groundnuts at Nhacoongo, 1980.[a]

Cultivar	Origin	Plant habit	Maturity	Shelled groundnuts (kg/ha)	Duncan test[b]
Bebiano Branco	Mozambique	Erect	Early	262	a
Tamnut	USA	Erect	Early	219	ab
55.137	Senegal	Erect	Early	212	ab
Malimba	Malawi	Erect	Early	210	ab
Bebiano Encarnado	Mozambique	Erect	Early	182	bc
Starr	USA	Erect	Early	155	bc
73.30	Senegal	Erect	Early	137	c
RMP-12	Senegal	Bunch	Medium	87	--
69-101	Senegal	Bunch	Medium	78	--
57-422	Senegal	Bunch	Late	60	--
Florunner (Senegal)	Senegal	Prostrate	Late	59	--
73.33	Senegal	Erect	Early	48	--
Mwitunde	Malawi	Bunch	Late	31	--
Manipintar	Malawi	Prostrate	Late	18	--

[a] The experiment was conducted in the southern part of the country.

[b] Cultivars ascribed the same letter are not significantly different in yield at the 5% level of probability.

Table 2. Yield of unshelled groundnuts at Namialo, 1981.[a]

Variety	Yield (kg/ha)	Duncan test (0.05)
57-422[b]	3611	a
Florunner	3333	ab
RMP-12[b]	3259	ab
Early Runner	2963	abc
59-127[b]	2796	bcd
69-101	2333	cd
Napalala	2278	cd
Manipintar	2206	d
Senegal[b]	1556	e
Local	1500	e

[a] This experiment was conducted in the northern part of the country.

[b] Obtained from Senegal.

Table 3. Yield of unshelled groundnuts at Namialo, 1982.[a]

Variety	Yield (kg/ha)	Duncan test (0.05)
Senegal	1340	a
Jonca[b]	1230	ab
Tamnut[b]	1060	bc
57-422	1060	bc
Starr[b]	900	cd
Maquilovilha	880	cd
Local	660	de
AC 207	600	e

[a] This experiment was conducted in the northern part of the country.
[b] Short-season varieties.

Farmers' Agronomic Practices

There is no definite seed rate used by the farmers. Depending upon the availability of seed at planting time, the seed rates for pure or mixed cropping may vary from 40-80 kg/ha. In the south, where seed shortage is very serious, farmers use less seed per hectare than in the north. In general, plant density is very low. Research results showed that erect varieties planted at high seed rates gave the highest yields. However, at a high plant population, the yield per plant and return on seed is lower than when plants are spaced far apart. Therefore, a high seed rate recommendation giving a high plant density may be an economic proposition for the state farms and private enterprises but not for the small-scale farmers who have difficulties obtaining sufficient seed to plant. Varieties that perform well at low plant densities should be identified and recommended for use by the small-scale farmer.

Groundnuts and all other crops are planted on the flat, even if the topography of the land warrants the making of bunds and ridges. Soil erosion is, therefore, a serious problem, especially in the north. Planting is always delayed and farmers recognize the loss in yield when groundnuts are planted late. However, they plant most land late because hoe cultivation is a slow process and, consequently, all other operations on the farm are delayed. The family labour force is commonly employed; although in the south, some farmers supplement this with animal traction. Rotation of crops and fertilizer application are not practiced but land may be left fallow for some time to allow it to recuperate.

INSTITUTIONAL ORGANIZATION

The Faculty of Agronomy and Forestry, University Eduardo Mondlane, was given full responsibility by the Ministry of Agriculture, through the National Institute of Agricultural Research (INIA), to carry out all research on groundnuts at the national level. There is, therefore, an intimate relationship between the Faculty of Agronomy and Forestry and INIA. Except for cotton, sugarcane, tea, and cashew, INIA is responsible for the organization, administration, and management of agricultural research on all other crops in the country.

Because groundnut production in Mozambique is linked with small-scale farmers, strong ties have been developed with national organizations that cater to this group, such as Zonas Verdes (Green Belt) and Cooperatives and Regional Centres of Extension and Development (CRED). An intimate relationship has also been developed with individual farmers. The project has close links with the National Agricultural Directorate (UDA), which is responsible for state farms.

Because seed multiplication is especially important for groundnuts in Mozambique, the project is working very closely with the National Seed Company in giving technical advice on seed multiplication, treatment, certification, and distribution. It is with the collaboration of the National Seed Company that the project is improving Bebiano Branco, a local landrace, using the mass-selection method. The improved version of the population is being multiplied and will be supplied to the farmers as seed.

The relationship between the project and the above-mentioned organizations is mutual. For instance, the Faculty of Agronomy and Forestry does not have research farms; instead, these are provided by the organizations free in exchange for the scientific and technical advice given to them by the project and with the understanding that research results are of direct benefit to them.

The project collaborates very closely with Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD) scientists working in Mozambique or there on short visits. Research on biological nitrogen fixation has been conducted by the project with FAO assistance.

Strong links have been developed with adjacent groundnut research programs in Zimbabwe, Zambia, Malawi, and Tanzania. There is now a reciprocal flow of research information, germ plasm, and exchange study visits. Farther afield, the project has a very close relationship with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which supplies exotic germ plasm. A joint project/ICRISAT local germ-plasm collection expedition was carried out in 1981 in northern Mozambique. ICRISAT has trained two technicians involved in the project and a third technician is currently taking part in an international course there.

IDRC recruited a senior scientist who, in collaboration with an agronomist, is carrying out research on groundnuts. As well, the researchers are teaching in their respective fields of specialization. This arrangement satisfies the additional objective of involving faculty staff and students in interdisciplinary agricultural research. Thus, apart from the plant breeder and agronomist, a plant pathologist is actively involved in groundnut research and scientific advice and assistance is obtained from other members of staff specialized in experimentation, chemistry, entomology, soil science, and rural development.

PROGRAM OBJECTIVES

The objectives of the project have two main components: (1) research in various aspects of groundnuts so that there will be an increase in production, and (2) training of Mozambican counterparts, field technicians, and workers so that research on this crop will be sustained.

Field surveys have been conducted by the project in all the major groundnut-growing areas. These have shown that there are several factors that limit groundnut production in Mozambique, such as a lack of farm implements and fertilizers; untimely planting, weeding, and harvesting; low plant density; and a lack of improved and high-yielding varieties resistant to diseases and insects. Every effort, therefore, is being made to revive and increase groundnut production through research aimed at identifying high-yielding varieties adapted to different agroecological zones. Such varieties should also be compatible with the present farming systems and trials are being conducted to encompass all aspects of the cultural practices employed by the farmers. To satisfy immediate needs, the project is screening a large number of varieties to identify those that are potentially high yielding. These varieties are then multiplied in collaboration with the National Seed Company and distributed to farmers as a stopgap measure until plant breeding can produce better varieties. An increase in groundnut production will greatly improve the level of nutrition of the rural and urban population. It will also mean that the country can export some of the produce to increase its foreign-exchange earnings.

The shortage of trained personnel is a serious problem in Mozambique. The project, therefore, attaches great importance to training national counterparts, field assistants, and workers. This will guarantee the continuity of the research work already initiated. Three graduates have worked in the project during the last year of their BSc course in agriculture. One of them will be working on a permanent basis in groundnut research and production. At the moment, the project is training two undergraduates in their third year of the BSc course. The aim is to give the candidates some experience in organizing and conducting research.

The project takes on a number of undergraduate students for special training in the field of agriculture under the university's extracurricular program.

A great deal of success has been achieved in training field assistants. These assistants receive their instructions from the project adviser and the agronomist. After sufficient exposure to the basic principles of agricultural science and research, they are recommended to participate in the international courses organized by ICRISAT. The project also organizes various forms of training for field workers in the project, members of farm cooperatives, and individual farmers. The underlying objectives of the training are to integrate theory with practice by stimulating students, lecturers, and assistants of the faculty to engage in agricultural research aimed at solving some of the basic problems farmers face in agricultural production. The project is also serving as the nucleus of the future postgraduate school and, at the same time, it is strengthening the national research capabilities through the exposure, guidance, and supervision of the students that pass through its program of work.

EVALUATION METHODS

The project has collected, maintained, and conserved a valuable germ plasm composed of exotic and local material. However, genetic resource conservation is only justified if such material can be utilized in crop improvement and crop production. Thus, systematic and quick methods of evaluation of the germ plasm so that promising material can be identified in a minimum of time and with a minimum of effort and cost should be devised. Through a multidisciplinary approach, in collaboration with an agronomist, a plant breeder, a pathologist, and a statistician, the groundnut germ plasm is evaluated in three stages.

Preliminary Evaluation of the Germ Plasm

The project has over 350 acquisitions and all of them have been evaluated for important agronomic and morphological characteristics such as yield, number of pods/plant, seed size and number of seeds/pod, shelling percentage, germination, flowering, vegetative cycle, pod maturity, and dormancy.

A description of plant morphology and habit has been made. This information is useful in deciding spacing within and between lines. Some of these varieties, pure lines, and segregating materials have been found to be high yielding and resistant to diseases such as rust and leaf spots.

Most of the germ plasm was bulked from a single plant or a few seeds so that there were delays of 2-3 years between the time that the line was acquired and the time that it was first tested. A preliminary observation nursery is used as an early testing technique of new material. However, there needs to be a balance between aiming for very early testing, through small unreplicated plots, and for gaining more reliable information from larger, replicated plots. A multilocation preliminary observation nursery is preferred because some acquisitions perform differently in different locations, e.g., material from Senegal proved to be excellent in the north but inferior in the south (Tables 1,2). If we had discarded this material in 1980, when it was first tested in the south, we might have lost the best material, so far obtained, for the north. It is, therefore, necessary to make a compromise between a screening method that is fast and one that is efficient enough to pick up superior material without expending too much energy and time.

Variety Yield Trials

The entries that performed well in the preliminary observation nursery are further tested in replicated multilocation variety trials. Data collected over 1 year are sufficient for a decision to be made on whether or not a variety should be tested further if the trial was truly multilocational; otherwise, more time is needed to obtain definite information about the performance of the varieties. Some of the varieties that had sufficient quantities of seed were evaluated directly in the variety yield trials. In these trials, no fertilizers were applied because this is how the farmers will eventually grow the crop. Through these experiments, varieties such as 57-422 and RMP-12 were recommended for the north and Bebiano Branco and Valencia were recommended for the south. The recommendation was based mainly on the yield potential rather than on disease resistance, so that even if a variety was susceptible to disease, but the disease did not appreciably decrease yield, the variety was considered to be superior.

Advanced Variety Yield Trials

The best varieties in the variety yield trials are further evaluated under the "farming systems approach." They are tested under different levels of fertilizers and intercropped with other crops. Data showed that some varieties gave high yields at high levels of fertilizer application and others at low levels of fertilizer application. With multilocation variety trials, varieties that respond to high levels of fertilizer application have been identified. Such varieties will be recommended for state farmers and cooperatives. Those varieties that are high yielding but that do not respond well to high levels of fertilizer application will be recommended for use by small-scale farmers. On-farm experiments showed that, under dryland farming, 3500 kg/ha of groundnuts were obtained when 40 kg/ha of P_2O_5 were applied, whereas the control gave 1000 kg/ha. These trials were conducted on farmers' fields and on land belonging to members of the cooperatives who collaborated and participated in running the trials. In one area in the south a positive response to zinc sulphate was obtained, especially if this fertilizer was applied together with phosphatic fertilizers.

Considering the magnitude and popularity of intercropping in Mozambique, varieties are evaluated under this practice so that specific information may be obtained on the type of species that may be intercropped, plant density, and the date of planting of each crop in the mixture. This is especially important in view of the fact that, at present, a lot of effort is being made to breed more productive varieties of all the major crops grown in Mozambique. Any such improved varieties placed in the hands of the small-scale farmer will be intercropped and the assumption that the best cultivars selected in a monoculture will also be optimal in a mixed-cropping system needs to be verified.

SUMMARY OF METHODOLOGICAL ISSUES

The government is placing great importance on small-scale farmers because they produce most of the food consumed in the country. In order that information on better crop production methods reaches the farmers, extension services through demonstrations, radio, and pamphlets are being organized. This means that the project has to examine more closely its objectives and research methodology to accommodate the official recommendations of rural development. Because groundnuts are almost entirely grown by small-scale farmers, the project's direct involvement in transforming subsistence farming into economic and increased crop production is quite evident.

So far, emphasis in research has been given to identifying and recommending high-yielding and, preferably, multiline varieties of groundnuts so that the immediate food requirements of the country and food preferences of the people are satisfied. Therefore, breeding objectives should aim at improving populations rather than releasing pure-line varieties. When there is an abundance of groundnuts, the farmers will become market-oriented and quality becomes an important factor. The breeding objectives will then have to change accordingly to suit such a demand. Farmers should be taught to use haulms profitably as livestock feed so that they may benefit from increased yields of milk. So far, farmers do not feed their livestock with groundnut fodder. Because animal traction is being strongly recommended as a cheap source of energy for the small-scale farmer, the project's identification of varieties whose foliage remains green at harvest is serving the dual purpose for the farmer of providing groundnuts as well as fodder.

Although intercropping is a popular practice, rotation is not common. There are several benefits associated with rotation and our future program should study this practice more closely and find a compromise between it and intercropping. When crops are rotated, fertilizer application is straightforward and easier than with intercropping. Some studies should be conducted on how to apply fertilizers to two different crops growing adjacent to each other in a mixture.

Although small-scale farmers do not use fertilizers, our program has a large component of fertilizer trials. Some of these trials have been carried out on farmers' fields in on-farm trials. After seeing a tremendous increase in crop yields, farmers are keenly interested in adopting this practice. Thus, our objective is not only improving existing practices but also innovating and introducing new ideas and technology.

The project has created and maintained close relationships with small-scale farmers so that, to many farmers, the project is synonymous with the Faculty of Agronomy. The project works closely with them from land preparation and planting through to harvesting. In this way, the project has managed to win the confidence of the farmers and they now turn to us for advice on their farm work. The project intends to intensify and improve this relationship because the whole objective of the groundnut improvement project is to help small-scale farmers raise their standard of living through increased food production and the economic benefits accruing from the sale of their produce.

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PULSE AND GROUNDNUT IMPROVEMENT IN TANZANIA

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Early man recognized the value of legumes as food for both human and animal consumption. Legumes are important because they are rich in protein. This is especially true of their seeds, which in many species contain 20-30% protein by weight, although up to 50% protein by weight has been reported in some soybean cultivars. Legumes that are cultivated for their mature seeds, for human consumption, are called pulses or grain legumes.

In addition to their importance as food, legumes are important because they replenish soil nitrogen. Nitrogen is the most limiting factor in primary production in spite of the fact that it is one of the dominant elements in nature, in the form of elemental dinitrogen (N_2). This form of nitrogen is unavailable to plants until it is converted into utilizable forms. There is an ever-increasing demand for nitrogen to maintain soil productivity. The global consumption of nitrogen fertilizer in 1973 was 40 million metric tonnes and it is estimated that the requirement for nitrogen fertilizer will be 200 million metric tonnes by the turn of the century (Hardy and Havelka 1975).

Tanzania, occupying an area of 930 000 km^2, contains different agroecological zones ranging from wet humid tropics to dry semi-arid areas. Due to its diverse ecology, it is well suited to growing different types of grain legumes. Prominent among them are kidney bean, groundnut, cowpea, soybean, green gram, pigeon pea, chick-pea, and bambara nut. These grain legumes are grown mainly for local consumption. However, attempts are being made to increase their production to alleviate protein deficiency among Tanzanians and to use some of them for oil extraction as well as for export. Unfortunately, there has not been much success in this direction, resulting in high market prices.

In view of the importance of grain legumes in Eastern African countries, in general, and Tanzania, in particular, coupled with their low productivity and high demand, a research project was developed in 1979. The project envisaged the inclusion of four grain legumes, namely: groundnut, soybean, green gram, and bambara nut. The choice of these legumes was based on the desire to keep the project at a manageable level. As well, some of the other grain legumes were included in other projects.

The broad objectives of the project were germ-plasm collection, evaluation, and, where necessary, to breed suitable varieties for the different agroecological zones of Tanzania. The specific objectives included: (1) development of cultivars that are high yielding, with high protein and oil content (groundnut and soybean), (2) development of early- and late-maturing varieties suitable for the different agroecological zones of the country, (3) incorporation or identification of drought resistance, (4) development of insect- and disease-resistant cultivars, (5) development of an agronomic package for farmers, and (6) training of personnel.

It may be pertinent at this point to deal with one crop in some detail instead of discussing all four legumes. This is because the methodology used for all of these crops is similar and the progress made also follows along similar lines. Therefore, this paper will review the progress, problems, and future of soybean improvement research within the scope of the project.

BACKGROUND TO SOYBEAN IMPROVEMENT RESEARCH

Soybean (*Glycine max* (L) Merrill) is said to be as old as the 5000 year old Chinese civilization (Senanayake 1982). It appears that it took about 4900 years for soybean to arrive in Tanzania (then Tanganyika), when it was first introduced in 1907 at Amani by Germans. Further introductions were made in 1909 (Auckland 1970; Mbaga 1974). Soybeans have since been grown at different times and places in Tanzania. During World War II, the British tried unsuccessfully to grow soybean in Kagera region. The low yields obtained could be attributed to poor varieties.

A renewed attempt was made to develop suitable soybean varieties at Nachingwea in 1955 and this program culminated with the development of varieties in 1963 that were suitable for low altitudes (0-900 m above sea level). Currently, most of the soybean is growing in Mtwara, Lindi, Kilimanjaro, and Morogoro regions (Anonymous 1974). Soybean is grown in monoculture as well as under intercropping.

PROBLEMS OF SOYBEAN PRODUCTION IN TANZANIA

Soybean has not been a popular crop in Tanzania, but it is becoming increasingly attractive to the peasant farmer as a result of some improvement in the pricing and marketing policy of the government. These improvements are in response to rising demands for vegetable oil, a protein source, and animal feed (Makena and Doto 1982). The current drive to boost soybean production is aimed at maximizing the full utility of the crop.

One of the major problems facing soybean is the lack of suitable varieties for the different agroecological zones of the country as well as poor nodulation with indigenous rhizobia. The latter problem is exacerbated by the uneconomic use of chemical fertilizers. Therefore, the present project was designed to address these problems and devise appropriate solutions.

INSTITUTIONAL ORGANIZATION OF THE PROJECT

The major portion of the investigations is conducted at the farms and laboratories of the Faculty of Agriculture, Forestry and Veterinary Science, University of Dar es Salaam, Morogoro. The faculty has a well-established farm of over 2300 ha in addition to well-equipped laboratories and supporting technical, laboratory, and field staff.

The pulses and groundnuts project funded by the International Development Research Centre (IDRC) is under the leadership of Dr. B.J. Ndunguru, who also serves as the legume agronomist. Responsibility for the success of the project also rests with the plant breeder because the major emphasis of the project is the improvement aspect of the crop. The plant breeder enjoys the collaboration and cooperation of two plant pathologists, three entomologists, one soil microbiologist, and a statistician. Essentially, the project is handled by a multidisciplinary professional team under the leadership of the project leader.

Project implementation and evaluation is an annual event involving all collaborators. At the end of each cropping season, the results of every experiment are discussed collectively and necessary changes or amendments are made in line with the objectives of the project.

There is a fair amount of cooperation between the faculty and various national institutions involved in agricultural research, e.g., Tanzania Agricultural Research Organisation (TARO), Uyole Agricultural Centre (UAC), Mbeya, and Tropical Pesticide Research Institute (TPRI), Arusha. From time to time, collaborative research is undertaken with these organizations. As well, the faculty has enjoyed a cordial relationship with various international agricultural research institutes such as the International Institute of Tropical Agriculture (IITA), Centro Internacional de Agricultura Tropical (CIAT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Rice Research Institute (IRRI), and Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). This relationship has contributed to the continuing exchange of germ plasm and to the training of personnel.

PROGRAM OBJECTIVES

The general objectives of the project have already been outlined, but the specific objectives in the case of soybean improvement are the development of: (1) high-yielding, nonshattering, lodging resistant, determinate types with pods between 12.7 and 15.2 cm from the ground for mechanical harvesting; (2) high-yielding, nonshattering, lodging resistant types but with no specifications with respect to habit, as they will be harvested by hand; (3) yellow, small seeds that will bring premium prices in the oriental market; (4) high oil and protein content types; (5) short-duration cultivars to be grown under irrigation, in rotation with major crops such as rice (Anonymous 1979); (6) adaptability to local environmental conditions; and (7) resistance to insects and diseases.

SPECIFIC OBJECTIVES AND SELECTION CRITERIA USED IN THE SOYBEAN IMPROVEMENT PROGRAM

Short-Stature and Short-Duration Plants

In Tanzania, most of the soybean crop is grown under marginal rainfall conditions where the rainfall is erratic and unreliable. Therefore, it is essential to have a short-duration crop so that maximum utilization of available moisture can be made. Plants that are of short stature require minimum nutrients and moisture and are easier to harvest.

Plants with Biological Nitrogen Fixation (BNF) Ability

The soybean varieties presently available in the country with high yield potential are poorly nodulated (Chowdhury 1977). Thus, they require additional nitrogen in the form of chemical fertilizer, making the crop uneconomical. There is a need, therefore, to develop soybean varieties that can nodulate with indigenous rhizobia.

Development/Selection of Soybean Varieties Resistant to Insects and Diseases

Even if one develops agronomically acceptable soybean varieties, if they eventually fall to insect and disease damage they will have to be replaced. Therefore, along with the development of short-stature and short-duration plants with BNF ability, regular screening against insects and diseases is required.

Presently, the important soybean diseases in Tanzania are cowpea mild mottle virus (CMMV), peanut mottle virus (PnMV), bacterial pustule (*Xanthomonas compestris* pv. *phaseoli*), *Cercospora canescence*, and *Phyllosticta glycine*. Phyllody, probably a mycoplasma-like organism, has been observed in Morogoro and Ilonga for the past several years. Among insect pests, termites (*Odonototermis lationotus* and *Odonototermes zambesiensis*) cause considerable damage during drier periods. In addition, stinkbug (*Nazara viridula*) and aphids (*Aphis glycine* and *A. gossypi*) can be a problem.

Soybean Varieties with High Oil and Protein Contents

This criterion is mainly included in our soybean improvement program in view of the acute shortage of cooking oil and animal feed in the country.

METHODOLOGY

The soybean improvement program at Morogoro is being carried out along the following lines: (1) germ plasm collection; (2) germ plasm multiplication; (3) single-row trials for preliminary screening; (4)

replicated trials within Morogoro Region; and (5) replicated multi-location trials.

While conducting (3), (4), and (5), the following observations are taken: Disease and insect damage is assessed to identify resistant varieties. BNF ability is studied to identify cultivars/lines that have the ability to nodulate with indigenous rhizobia and, thus, fix atmospheric nitrogen. The acetylene-ethylene reduction method is an easy and fast method of testing for BNF ability (Hardy et al. 1968). Regular screening of crosses is made for oil and protein content to identify suitable germ plasm for hybridization or multiplication purposes.

SUMMARY OF METHODOLOGICAL ISSUES

Although only the soybean improvement program has been discussed in this paper, the four legumes (i.e., groundnut, soybean, green gram, and bambara nut) studied in the broader project are treated along similar lines. However, in view of logistics/manpower, transport, materials, germ plasm, and limited irrigation facilities, considerably more emphasis has been placed on groundnuts and soybean. So far, no hybridization has been conducted in the case of green gram and at present the accessions are being evaluated. Similarly, bambara nut, with only 11 accessions, is being increased. The work on groundnut and soybean is progressing well and we hope that it will continue in the future.

The grain legume improvement project is only a little more than 2 years old. Therefore, it would be unrealistic to pinpoint the specific achievements of the project. However, it may be mentioned that above-average progress has been made with respect to hybridization between soybean varieties Bossier and 1H/192. Some of the selections now in the F_8 stage are better than both parents in terms of our defined objectives, i.e., size, short duration, BNF ability, and yield (Chowdhury and Doto 1982). This material should go into multilocation trials in December 1983 and a couple of lines may be released as varieties by 1985.

In the case of groundnuts, we have a good germ-plasm collection that includes lines/varieties from India, Tanzania, Mozambique, Zimbabwe, Malawi, Zambia, Kenya, and Uganda. Initial crosses between several lines/varieties have already been accomplished and during the coming season the material should undergo further trials across other locations, apart from Morogoro.

More than 70 lines of green gram are being evaluated for various agronomic characteristics and yield. Selections from these trials will go into the hybridization process during the coming season.

The weakest area in the project is bambara nut, of which we have been able to collect only 11 samples. To pursue this crop vigorously we need to acquire more germ plasm, especially from West Africa.

Although this project is being undertaken at Morogoro, Tanzania, we aim to develop various grain legume varieties that could be beneficial not only to our country but also to other neighbouring countries (three lines of our soybeans have already been sent to the International Soybean Program (INTSOY)) with similar agroclimatic conditions. We hope to achieve these goals with close cooperation between researchers from other countries.

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ON-FARM TESTING OF IMPROVED PIGEON PEA (CAJANUS CAJAN (L) MILLSP.) CULTIVARS IN KENYA

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Pigeon pea (Cajanus cajan (L) Millsp.) is the most important grain legume in the marginal rainfall areas of Kenya, where it covers an area of approximately 100 000 ha annually. Because of its importance in marginal rainfall areas, the pigeon pea improvement project (PPIP) was initiated in the Department of Crop Science, University of Nairobi, in 1975 to improve grain yields under marginal rainfall conditions.

Information on grain yields of pigeon pea in Kenya is lacking. Even figures on national average yields of pigeon pea for Kenya were not available. Work published elsewhere revealed that grain yields of pigeon pea varied widely. The highest pigeon pea grain yields of 7500 kg/ha have been reported by Akinola and Whiteman (1972) from Australia, where the crop was planted in pure stand under experimental conditions. In experimental plots under pure culture and irrigation, Onim and Rubaihayo (1976) reported pigeon pea grain yields of 4250 kg/ha from Uganda. Under mixed cropping in farmers' fields in Uganda, Laker (1970) estimated pigeon pea grain yields at 560 kg/ha, whereas Dunbar (1969), also in Uganda, estimated yields under similar conditions to be 168 kg/ha. Although these yield estimates may not have been accurately determined, the yield gap between the farmer and the researcher is very large. According to the reports of Dunbar (1969), Laker (1970), and Onim and Rubaihayo (1976), this gap between the researcher and the farmer in Uganda is between 659 and 2430% (difference based on farmers' yields). There can be many causes contributing to this tremendous gap. Some causes that are generally blamed on the farmers could be due to one or a combination of the following factors: (1) use of inferior crop varieties; (2) lack of inputs such as fertilizers, pesticides, or sufficient labour; or (3) poor crop husbandry, e.g., late planting, inadequate weeding, or low crop densities.

Studying the effects of these possible causes of low yields at the farmers' level and their interactions is not a simple task. It was decided, therefore, for the purpose of this study, that only one cause would be investigated. The one chosen was the use of improved seed versus the farmers' own cultivars.

DEVELOPMENT OF IMPROVED PIGEON PEA CULTIVARS

A large number of pigeon pea cultivars were collected from farmers' fields in Machakos and Kitui districts of Kenya in 1976 for inclusion in the then existing germ-plasm bank in the Department of Crop Science, University of Nairobi. This germ-plasm collection was evaluated in 1977 at the National Dryland Farming Research Station of the Ministry of Agriculture, at Katumani, and several single plants were selected and selfed. In 1973, 11 of the highest yielding single plant selections were tested further in a replicated yield trial at three research stations located in distinct ecological zones: Kiboa in Kisumu, Thika in Central Province, and Kampi ya Mawe in Machakos District. The six highest yielding selections at the three locations were selected for further testing in farmers' fields in 1979.

TESTING OF SIX IMPROVED PIGEON PEA CULTIVARS IN FARMERS' FIELDS IN MAKUENI DIVISION, MACHAKOS DISTRICT

Site Selection

The assistant agricultural officer (AAO) of Makueni Division was approached and asked to select a sublocation where the six improved pigeon pea cultivars could be tested in farmers' fields. Muvau was chosen and the extension agricultural officer of Muvau was then asked to compile a long list of farmers from Muvau. In compiling the list, no selection criteria were to be used so that both better-off and poorer farmers would be included. When the list was ready, every 10th name was chosen and a total of 12 farmers were selected. These were supplied with 3 kg of pigeon pea seed of the improved cultivars (two farmers for each cultivar).

Crop Husbandry

The farmers were told to plant half of their field with the improved cultivar and the other half with their own variety. They were further instructed to use crop husbandry methods of their choice, e.g., intercropping/pure stand, spacing, weeding frequency, etc. At flowering time, the PPIP staff and the extension officer from Muvau began visiting the farmers to monitor crop development.

Data Collection

At maturity, data were jointly collected from the fields by PPIP staff, the extension officer from Muvau, and members of the farmer's family.

A quadrat measuring 3 m X 3 m was placed in a representative part of the field of the improved cultivar and the following data were collected: number of plants in the quadrat, number of wilted plants in the quadrat (wilt caused by *Fusarium udum* Butl.), plant height of five randomly selected plants, and number of primary branches on the five randomly chosen plants. The plants within the quadrat were then harvested. The same data were collected on the farmer's own variety. A visual estimate of the yields of both the improved and farmer's cultivars was made on the spot by direct comparison. This simply involved counting the number of paper bags (size 25) filled by each of the test cultivars. The three representatives from the project, extension service, and farmer's family then agreed on which of the two cultivars performed better in the particular field. Eight of the 12 farms were harvested successfully in this manner.

The rest of the field of the improved cultivar was harvested separately and threshed on the spot. The produce was weighed and the farmer was paid for it 2 weeks later.

The pods from the quadrats were taken back to Nairobi where more data were obtained, including: the percentage of pest-damaged pods and seeds, the 100-seed weight, and grain yield from the quadrat. These data were then converted to yields per hectare.

Results

Of the 12 test farmers, four harvested the improved cultivars before we arrived. Therefore, these were not included in the results. In one or two cases, the fields were not properly weeded. In other respects, the experiment was considered to have been well executed.

Some of the data on the improved and farmers' cultivars are presented in Table 1. Plant densities used by the farmers for both their varieties and the improved cultivars were similar in all cases; therefore, a mean of the two estimates has been used for each field. Comparisons between the farmers' and improved cultivars did not show major differences among any of the characteristics measured except grain yields. The mean grain yield of the improved cultivars in eight fields was 2637 kg/ha, whereas that of the farmers' cultivars was 1361 kg/ha. The improved cultivars, therefore, yielded more than the farmers' cultivars by 93.8%. The two varieties with the best grain yield yielded 4262 and 4602 kg/ha respectively. Two of the improved cultivars, however, broke down with Fusarium wilt. In the same fields, the farmer's cultivar suffered a mild attack in one case, whereas in the other the farmer's cultivar showed 100% resistance. In both cases, the farmers were fully compensated for the lost yields due to the susceptibility of the improved cultivars.

The extent of pest damage in the farmers' fields was much lower than had been anticipated. Moreover, the level of pest damage seemed to be much lower in the farmers' fields, with means of 9.2 and 2.5% for pods and seeds, respectively, than the 20.6 and 5.3% obtained for pods and seeds, respectively, under research station conditions (Table 1). From the results of this study, three cultivars were selected for further prerelease testing in farmers' fields. Two kilograms of seed of two of the best yielding cultivars were distributed to 300 farmers in Muvau sublocation for the October 1980 planting, while these high-yielding selections and one more were given to 12 farmers (three farmers per cultivar) in Kitui District for a similar pilot trial -- researcher-farmer cooperative trials -- as was done earlier in Muvau.

The results from this study indicated that more information should be made available on this crop at the farmers' level. Therefore, two surveys were conducted in Machakos and Kitui districts in 1979 and 1980. The primary objectives of these surveys were to determine grain yields of pigeon pea at the farmers' level in Kenya, and estimate losses due to diseases and pest damage on pigeon pea in farmers' fields. Quadrats measuring 3 m X 3 m were used, as described earlier, and similar data were collected. In both surveys, pigeon pea fields approximately 20 km apart along major and medium-sized roads in

Table 1. Plant densities and comparison of grain yields, 100-seed weight, and pest damage between farmers' varieties and improved pigeon pea cultivars in farmers' fields in Kenya.

Field no.	Plant population/ha	Grain yield (kg/ha)		100-seed weight (g)		Pest damage (%)			
						Pods		Seeds	
		Farmer's	Improved	Farmer's	Improved	Farmer's	Improved	Farmer's	Improved
1	11100	1014	1515	22.64	20.47	10.6	5.6	3.0	1.2
2	21100	2093	2197	24.66	19.87	15.5	6.7	3.1	2.0
3	34400	1251	2567	22.16	25.06	7.8	9.8	3.2	3.2
4	14400	731	4262[a]	21.25	17.32	9.0	9.0	3.0	5.0
5	32200	2150	2476[a]	21.72	22.84	3.6	9.5	1.0	2.4
6	23300	1763	4602[a]	22.88	24.08	12.3	4.2	3.5	1.5
7	22200	804	1418	25.57	22.42	13.3	10.0	3.0	3.3
8	22200	1081	2019	24.34	21.42	8.3	10.9	2.7	3.1
9[b]	35600				20.60		22.2		6.9
10[b]	37800				23.60		18.9		3.8
Mean	25430	1631	2637	23.15	21.77	10.1	10.7	2.8	3.1

[a] Cultivars selected for further prerelease testing.

[b] Improved cultivars planted at recommended plant density at Kampi ya Mawe Research Substation.

Table 2. Plant densities, height, number of primary branches, grain yields, and pest damage of pigeon pea in farmers' fields in Kenya.

Field no.	Population/ha		Plant height (cm)		Number of primary branches		Grain yield (kg/ha)		Pest damaged pods (%)(1980)
	1979	1980	1979	1980	1979	1980	1979	1980	
1	23300	11100	347.4	289.0	25.6	17.8	1028	1014	10.6
2	12200	21100	305.6	284.6	27.0	19.6	1186	2093	15.5
3	43300	34400	345.2	259.2	22.6	19.2	1242	1251	7.8
4	18900	14400	274.8	306.0	19.4	28.0	1450	731	9.0
5	17780	32200	333.8	252.2	22.8	19.2	1903	2150	3.6
6	11100	23300	339.4	239.0	26.0	24.6	1532	1763	12.3
7	21000	22200	288.2	217.2	19.4	12.2	1600	804	13.3
8	12200	22200	259.6	293.4	19.2	21.4	1431	1081	6.3
9	10000	35600	263.2	289.0	21.2	23.8	1191	606	22.2
10	11100	37800	264.8	271.8	19.4	14.2	2493	1012	18.9
11	10000	41100	272.2	284.0	23.8	15.2	1229	1553	5.4
12	21100	17800	368.0	213.0	28.0	12.8	2136	691	25.4
13	25600	33300	331.0	199.6	26.6	11.6	980	699	14.5
14	24400	17800	345.6	253.8	26.2	18.8	1019	862	17.0
15	15600	14400	343.0	243.6	26.4	18.0	1868	729	12.0
16	28900	64400	291.6	245.2	24.4	14.2	938	516	15.7
17	18900	10000	325.4	274.4	25.0	18.4	1449	1286	19.5
18	13300	25600	334.2	289.0	30.4	17.2	1866	1186	14.4
19	12200	20000	336.6	301.2	25.6	19.2	1153	2018	13.4
20	31100	18900	351.2	321.6	27.0	18.6	2202	1192	7.3
21	22200		357.8		26.4		1931		
Mean	19251	25900	318.0	266.4	24.4	18.2	1492	1162	13.6

Machakos and Kitui districts were surveyed. Twenty-one fields were surveyed in 1979 and 20 in 1980. The results of these surveys are presented in Table 2.

The mean population density used by farmers in Machakos and Kitui districts in 1979 and 1980 was about 22 600 plants/ha. This density gave mean grain yields of about 1300 kg/ha over the 2 years. The mean plant height was 292 cm and the number of primary branches was 21 over the 2 years, whereas the mean pest damage to pods in 1980 was 14%.

DISCUSSION

The large yield gap between the researcher and the farmer should be narrowed. This can be tackled from two possible angles: (1) Researchers should continue their research at research stations but cost their inputs and view the realized yields on an economic basis. (2) Researchers should test their recommended crop packages in farmers' fields using the farmer's own production system. In this study, both approaches have been used and the results have had a very large impact on the farmers. The wisdom of farmers and their farming experience is often underrated by research workers. Two examples of the farmers' wisdom and expertise have clearly emerged from this study. In the first case, two of the improved cultivars broke down in the farmers' fields with Fusarium wilt, whereas the farmers' own cultivars were able to withstand the disease. In one case, the farmer's cultivar was 100% resistant, whereas the improved cultivar was 100% susceptible. Farmers have had very high disease levels in their fields over the years and they have been selecting for resistant cultivars all along. The farmer has come up with a very resistant cultivar to this wilt disease. We have leased this particular farmer's field to use as a disease nursery for screening germ plasm for Fusarium wilt resistance.

The second case concerns the choice of plant population. The recommended spacing for pigeon pea in Kenya is approximately 40 000 plants/ha. This density is too high for a marginal rainfall area. The farmers, on the other hand, use lower densities. In 1980, the recommended densities (field numbers 9 and 10 in Table 2) resulted in a mean lower yield of 809 kg/ha compared with the overall farmers' average of 1200 kg/ha.

The results presented in this paper indicate that by giving the farmer improved cultivars, yields can easily be doubled. The results obtained in the farmers' fields with their own efforts and inputs are much more convincing to them, and adoption of such cultivars by farmers should be much easier than those released by research stations. The results also show that pigeon pea yields at the farmers' level in Kenya are very high. This makes the estimates of Dunbar (1969) and Laker (1970), in Uganda, rather doubtful.

Pest damage at research stations tends to be higher than in the farmers' fields. There are many reasons for this. This study seems to have brought out this fact, as is shown in Table 1. It is important, therefore, that before making blanket recommendations, which emanate from research stations, researchers should appraise the situation in the farmers' fields.

Finally, this study has been a learning process for both the farmer and the researcher -- a fact that is very encouraging.

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ROOTS AND TUBERS

ROOT-CROPS PROGRAM, ZANZIBAR

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Cassava is grown throughout Zanzibar and Pemba on well-drained, sandy red soils. On both islands, these soils support mainly tree crops (cloves on Pemba and cloves, coconuts, and fruit trees on Zanzibar). On the more fertile soils, bananas and cocoyams are grown. Cassava is cultivated on poor, light soils, frequently under mature coconuts or where the tree cover is less dense. The coral soils on the eastern half of both islands support cassava in areas of deeper soils. Where the soil depth is sufficient, cassava is grown on ridges approximately 1 m apart. Ridging is used to prevent waterlogging during the extensive rains from March to May (Masika) and November to December (Vuli). It is also practiced as a soil conservation measure, aids deep root development, and facilitates root removal at harvest. The interplant spacing is generally 1 m (10 000 plants/ha). The main planting season is after the Masika rains, with a secondary planting season during the Vuli rains. These planting times, however, are not restrictive as Zanzibar does not suffer from a prolonged dry season. Cassava is planted when moisture becomes adequate.

Cassava is most frequently intercropped with sweet potatoes, although other short-term crops such as maize, groundnuts, and tomatoes are also used as an intercrop. On Zanzibar, according to the 1982 report on the implementation of agricultural work (Ministry of Agriculture, unpublished data), 18 409 ha were planted with cassava and 6448 ha with sweet potatoes, producing a yield of 6.3 and 6.8 t/ha respectively. The average size of a cassava farm is 0.4 ha (Carpenter 1980).

There are about 20 local varieties of cassava grown on Zanzibar. Most are considered "sweet" tasting and are classified according to their time to harvest: short term (6-9 months) and long term (12-18 months). Delays in harvesting cassava roots result in excess thickening and an increased fibre content, thus spoiling the root quality. The cassava is frequently tested by farmers in the fields where it is judged to be bitter or sweet. The tubers are commonly eaten boiled in coconut milk. About 30-40% of the cassava yield (generally the bitter types) is split, dried in the sun, and ground into flour. Some cassava, after being split and dried, is fermented for 12-24 hours and then boiled and mixed with coconut milk to form a very common Zanzibar dish called "makopa." The cassava leaves (kisambu) are cut once or twice during the plant's growing season and are eaten as a vegetable throughout the island. The people of Zanzibar believe that one or two cuttings of kisambu help root development, but frequent cutting is avoided as it stunts growth and reduces yield. At one time, cassava was used as cattle feed but due to population increases and the low yield characteristics of local varieties almost all cassava is now grown for human consumption. Much cassava is sold in the town of Zanzibar, where urban tastes determine which varieties are brought to market.

The cassava program is jointly funded by the Government of Tanzania and the International Development Research Centre (IDRC) of Canada. Officially the project began in 1976 for a period of 3 years. At that time, CA$54 000 was donated by the sponsors as an operational and capital budget, while the Zanzibar Ministry of Agriculture provided land for project work and salaries for the workers. Since the initiation of the program in 1976, Dr. Allan Carpenter of the Food and Agriculture Organization of the United Nations (FAO) has assisted in the development of the program. At present, the program staff includes two agronomists, one field officer, and several field assistants. Most of the field assistants have certificates in general agriculture and some have attended short courses in specialized fields at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria.

PROGRAM OBJECTIVES

The broad objectives are: (1) to screen, under local conditions, root crop germ plasm imported from IITA to identify high yielding and disease and pest resistant varieties; (2) to institute a multiplication program of promising varieties; and (3) to assist in the diploma and degree training of Tanzanians in agriculture abroad.

Most local varieties, although sweet tasting, are low yielding and are highly susceptible to cassava mosaic disease (CMD) and to infestation of green mites (GM) (*Mononychellus tanajoa*). As mentioned earlier, the population increase has placed a heavy demand on cassava production and, thus, the emphasis on selecting for high yielding and disease and pest resistant varieties. However, as most cassava is eaten fresh (i.e., not dried and made into gari or similar flour products), its palatability is also an important criteria. The project has not started a plant-breeding program as IITA provides adequate improved germ plasm.

In the area of agronomic adaptation, the project is selecting varieties for: (1) shade tolerance -- cassava in Zanzibar is planted under mature coconuts due to competition for land with several other crops such as bananas, cloves, and citrus fruits (cassava production is reduced by heaving shading); (2) intercropping -- vertical, high-branching varieties as opposed to low, horizontal-branching varieties are better suited for intercropping with regard to shading and accessibility to the intercrop; and (3) weed suppression -- in areas where cassava is grown as a sole crop or at some distance from the home, frequent weeding is unlikely; thus, weed suppression would be a factor affecting yield increases as well as facilitating harvesting.

At present, the program has undertaken: (1) intercropping trials, e.g., cassava and groundnuts, cassava and upland rice, cassava and sweet potatoes; (2) shade tolerance trials under immature and mature coconuts; (3) cassava varietal trials involving IITA varieties and local varieties and trials involving IITA sweet potato varieties and local varieties; (4) multilocational trials testing IITA varieties under different soil conditions on the islands; (5) trials to determine the opportune time to plant a particular variety, with reference to yield and disease and pest resistance; and (6) multiplication plots of selected IITA varieties.

EVALUATION METHODS

Multilocational trials are usually established on research stations, as the project has access to these lands. The initial selection of the site and planting and harvesting are performed under supervision and by workers from the main experiment station (Kizimbani). Land preparation and maintenance of the plots (e.g., weeding) are undertaken by project workers. The trials are checked as frequently as possible and scoring for CMD and GM resistance is performed by project field assistants.

Cassava cuttings are distributed free of charge to farmers throughout Zanzibar. The farmers are advised as to basic planting practices, i.e., ridging and spacing. They generally receive 10-20 stakes as the project's major limiting factor is the multiplication rate of varieties for distribution. The project has little control over whether or not the cuttings are planted with an intercrop and the frequency of weeding. The project attempts to do a follow-up study on each farmer within 4 months of the distribution of the cuttings.

The varieties' resistance to GM and CMD is evaluated using standard scoring scales from IITA. Counts are made as to the number of plants infected with GM or CMD. Yield is determined on a fresh-weight basis at maturity. Root characteristics such as skin colour, neck length, and shape are also evaluated using IITA guidelines. The tubers undergo two palatability tests; raw in the field and after boiling until soft. Workers involved in the harvest evaluate the cassava varieties for palatability.

In the Zanzibar market, 1 kg of tubers sells for TZSh10. The average cassava production is 4-6 t/ha, thus giving a gross return of TZSh40 000 (US$3333). The expected yield with the IITA improved varieties is 20-30 t/ha; hence, a return of TZSh200 000 (US$16 666), an increase of TZSh160 000 (US$13 333).

The program has had some difficulty in obtaining accurate data from experimental sites other than Kizimbani. Soil test results are not available for any of the land under cassava trials. The farmer's small average plot size precludes accurate yield data (i.e., 10-20 plants of cassava per farm) and in the usual case the inaccessibility of the on-farm cassava trials prevents frequent follow-up studies by the project. Also, many of the varieties distributed by IITA are highly suitable for the production of gari (flour) but not simply through other methods of preparation used in Zanzibar such as boiling.

SUMMARY OF METHODOLOGICAL ISSUES

The objectives of the project have not changed over the past years although at present emphasis is being placed on distribution of the IITA cuttings to farmers. The project also prefers to work directly with the farmers rather than through an intermediary. This ensures that the farmers actually receive the cuttings. A rapid multiplication hut is being built to aid in the quick multiplication of IITA varieties for distribution. The project continues to assist Tanzanians in agricultural training, which is an important aspect of the program.

The most interesting features of the program are the high root-yielding ability of the introduced varieties and their suitability for "kisambu." Some farmers actually steal the leaf cuttings to test them in their own fields. The high potential of the IITA varieties to produce good "kisambu" forces the project to post guards at field trials at Kizimbani to prevent the cutting of the leaves.

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SWEET POTATO CULTIVATION AND RESEARCH IN RWANDA

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Recently, a great deal of effort has been placed on increasing food-crop production in Rwanda (Bazihizina 1983). The sweet potato, a widely cultivated crop, is one of the agricultural products under investigation. It grows at elevations up to 2300 m above sea level. The highest production, however, is obtained at elevations up to 1900 m, above which the crop suffers from low temperatures.

The sweet potato performs very well in all 12 agricultural regions of the country (Fig. 1; Table 1), except in the northern region where there are volcanic soils (Delepierre 1974). It occupies 94 000 ha of land and has a total production of about 782 400 t (Ministry of Planning 1975–1980), representing 20% of the country's food production. It is, therefore, the second most important crop after banana. Table 2 shows the production of sweet potatoes in nine districts of Rwanda.

PRODUCTION SYSTEMS

In rural areas, the sweet potato is cultivated on fallowed land. It is either cultivated alone or in a mixture with beans, sorghum, or cassava. From September to April, it is cultivated on the slopes of hills, whereas from May to July it is cultivated in valleys, which have usually been flooded during the rainy season. Thus, sweet potatoes are available year-round.

In the flooded valleys, large ridges are made so that good drainage is achieved. On the slopes of hills, sweet potatoes are planted either on ridges or bunds.

RESEARCH ORGANIZATION

The Institut des sciences agronomiques du Rwanda (ISAR), whose headquarters are located in Rubona, with the help of the Ministry of Agriculture and Livestock, has conducted research aimed at finding solutions to the various problems that agriculture is facing.

The departments carrying out these studies include the Plant Production Department, Animal Production Department, and Land Management Department, with the help of the Laboratories Department

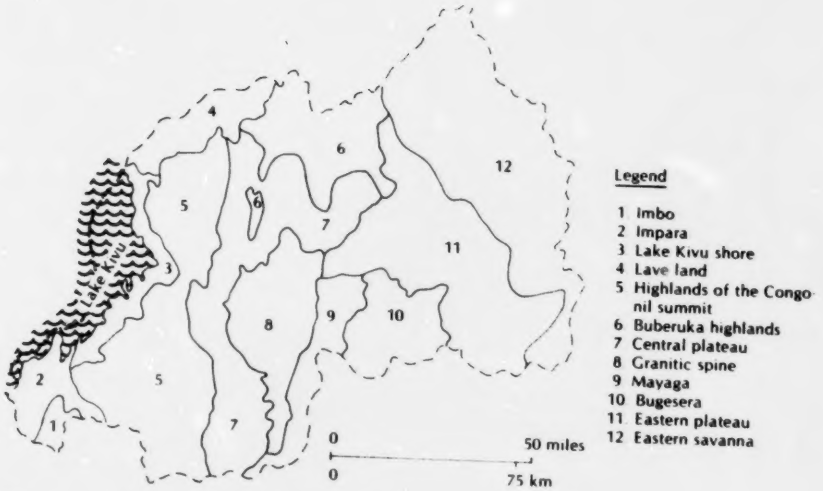

Fig. 1. Agricultural regions of Rwanda.

(chemistry, technology, plant protection) and the Farming System Service, which is concerned with diffusion of research results to local farmers.

The Plant Production Department is made up of five divisions. The Food Crops Division conducts its research in five areas of the country (Rubona, Rwerere, Karama, Ruhengeri, and Tamira) on the selection, improvement, and agricultural techniques of cereals, grain legumes, and root and tuber crops in an attempt to find the most suitable varieties for each ecological zone.

The root and tuber crops research program is organized and stationed according to different ecological conditions: for the sweet potato, yam, and cocoyam at Rubona; cassava at Karama; and Irish potatoes at Ruhengeri. The Irish potato program is well staffed, whereas the sweet potato and cassava programs are not yet self-sufficient with respect to research staff, each program having at present one agronomist/breeder.

PROGRAM OBJECTIVES

Main Factors Limiting Production

During the past 10 years, there has been an increase in total cultivated area but the output remains stagnant or, in some cases, is decreasing. This is due to various factors.

Pests and Diseases

Virus diseases -- These constitute viral complexes that are not yet identified. They are transmitted mainly by aphids (*Myzodes persicae*) and white flies (*Bemisia tabaci*). Virus diseases can reduce total production by 50% or more.

Table 1. Summary of agricultural regions.

Region	Altitude (m asl)	Rainfall (mm)	Soils	Main products	Agricultural value
Imbo	970-1400	1050-1600	Alluvial soils	PLANTAIN, CASSAVA, beans, peanuts, sweet potatoes, COTTON, RICE, sugarcane, citrus fruits	Excellent
Impara	1400-1900	1300-2000	Heavy red soils derived from basalts	Plantain, beans, maize, sorghum, sweet potatoes, cassava, peanuts, COFFEE, TEA, Peruvian bark	Good
Shore of Lake Kivu	1460-1900	1150-1300	Clay loam surface soils	Plantain, beans, maize, sorghum, sweet potatoes, cassava, peanuts, COFFEE	Bugoyi and Kanage, excellent; the others, good
Lave land	1600-2500	1300-1600	Volcanic soils	Plantain, beans, maize, sweet potatoes, sorghum, peas, potatoes, WALLWORT, TOBACCO	Excellent
Summit	1900-2500	1300-2000	Humic, acidic soils	PEAS, maize, potatoes, *Eleusine* sp., buckwheat, SUMMER WHEAT, TEA, SUNFLOWER, LUMBER	Fair
Buberuka	1900-2300	1100-1300	Lateritic soils	Plantain, beans, sorghum, sweet potatoes, maize, potatoes, PEAS, SUMMER WHEAT, barley	Good

Central plateau	1500-1900	1100-1300	Different humic soils	BEANS, sorghum, maize, SWEET POTATOES, plantain, taro, yams, coffee, soybeans	Good
Granitic spine	1400-1700	1050-1200	Light, gravelly soils	Plantain, BEANS, sorghum, maize, SWEET POTATOES, yams, taro, peanuts, cassava, coffee, livestock	Fair
Mayaga	1350-1500	1000-1200	Clay soils derived from slates	COFFEE, BEANS, SORGHUM, maize, plantain, sweet potatoes, cassava, peanuts, soybeans, rice	Very good
Bugesera	1300-1500	850-1000	Clay, highly altered soils	Beans, sorghum, maize, plantain, sweet potatoes, CASSAVA, peanuts, livestock	Poor
Eastern plateau	1400-1800	900-1000	Lateritic soils	Beans, sorghum, maize, PLANTAIN, sweet potatoes, cassava, PEANUTS, livestock	Fair in the north, good in the south
Eastern savanna	1250-1600	800-900	Old soils of variable texture	Cassava, peanuts, beans, sorghum, maize, sweet potatoes, livestock	Very poor

Table 2. Sweet potato production in different districts of Rwanda, 1975-1979.

District	Production (%)	Yield (t/ha)
Butare	17.6	10.6
Gitarama	11.8	8.3
Kigali	11.8	7.9
Byumba	10.6	7.0
Gikongoro	10.4	7.7
Gisenyi	9.8	8.1
Kibungo	7.5	8.9
Cyangugu	7.0	8.9
Ruhengeri	6.6	6.6

Fungal diseases -- Among the most important fungal diseases that attack sweet potatoes in Rwanda is anthracnose leaf spot, which is caused by *Alternaria solant*. Attack by this fungi can easily result in the *total destruction of* the crop. Anthracnose is more dangerous in high-altitude regions.

Virus and fungus diseases are spread vegetatively, especially during the period when cuttings are obtained. Hence, it has become a problem because these diseases are present even before planting.

Weevils -- The black weevil (*Cylas* spp.) attacks almost every part of the plant, but the roots *in particular*. The weevils bore through the roots or stems and at the same time leave their feces behind. The weevils cause the tubers to rot in the fields during the dry seasons; hence, they become unfit for consumption.

Early-maturing varieties are more susceptible to attack by weevils. Damage by weevils is a problem in almost all regions where this crop serves as a main food source for the population.

Leaf caterpillars -- During the dry season, the larva of the moth *Acraea acerata* completely eat the sweet potato leaves. The speed *of their attack is* exceptionally rapid during this period. Damage due to the leaf caterpillar, in 1983, was exceptionally high throughout the country.

Institutional Constraints

Results obtained at research centres do not reach farmers easily. Therefore, farmers concentrate more on using local varieties and traditional techniques.

Production increases are difficult to achieve using traditional agricultural practices that do not involve weeding. Extension personnel have not yet reached farmers in sufficient numbers to encourage them to change from their traditional agricultural practices to the modern intensified techniques that have been developed.

Low Temperatures and Drought

Even though sweet potato varieties are adaptable, they are very much affected by cold in high-altitude regions. Droughts, on the other hand, reduce production in the low-altitude eastern parts of the country.

Planting Date

Farmers tend to plant sweet potatoes late, after they have completed the sowing of grain legumes and cereals, e.g., from April to mid-September the weather is not suitable for planting sweet potatoes on hills or hillslopes; in the flooded valleys planting is carried out from May to July.

Diffusion of Material

Attempts to diffuse materials are facing difficulties of a low production rate of the planting materials. The coefficient of production is about 5, whereas the coefficient of production in a well-managed nursery reaches 15 at a single harvest, which can be conducted three times a year.

Soil Fertility

The level of soil fertility is usually poor. Hillslope soil that is poor in organic matter is another of the many factors that all combine to reduce sweet potato production.

Research Objectives

The main objective of the research program on the sweet potato is to increase production. This can be achieved by the selection of local and exotic material and by the breeding and selection of new varieties having the highest yield of dry matter and high resistance to diseases and pests that reduce yields.

We are attempting to find those varieties that will be tolerant to drought, humidity in the deep valleys, and low temperatures at high altitudes. Particular attention is being placed on adaptability to different types of environments and improvement of quality (nutritive value and taste). The affect of agricultural techniques on fertility, mixed cropping, tuberization, productivity, planting patterns, and preextension are being studied in pilot projects in the hills near ISAR stations.

Selection and improvement in the research program comprises four components: (1) selection of local and exotic varieties -- this involves yield trials (carried out over two seasons) and replicated multilocational trials (carried out over four seasons) using the best varieties obtained from the yield trials; (2) plant breeding -- this is carried out through a selection cycle that goes from seeds to nursery (August) to selection fields (one season) to clonal evaluation (one season) to preliminary yield trials (two seasons) to yield trials (two seasons) and, finally, replicated multilocational trials (four seasons) of the 15 best varieties; (3) agronomic practices -- these are developed for the best varieties; and (4) preextension of recommended agronomic techniques and the best varieties -- the varieties used are chosen from the varietal comparative trials (one or two seasons in the farmer's field).

Selection and Breeding

The first varietal introduction dates back to 1930, when research on the sweet potato was based at the Institut national des études agronomiques au Congo (INEAC), Mulungu, in Zaire. It was only interested in the introduction of these varieties for adaptation in Rwanda and conducted some yield trials on local and exotic materials.

A well-structured research program on the sweet potato started in 1978 and the first attempts to cross varieties began in 1979. Actually, the first selections were made at the yield and multilocational comparative trial levels.

METHODOLOGY

Breeding Base Populations

Initially, we concentrated more on gathering local germ plasm, particularly that which will adapt best to the varied ecological conditions of this mountainous country. In addition, we looked at exotic materials in the form of seeds or clones. In looking at varieties from neighbouring countries, there is a chance of discovering those types that are adaptable, particularly varieties originating from regions with ecological conditions similar to those of Rwanda.

To obtain a good base population at the time of intervarietal hybridization, it is necessary to choose good parent material. The choice of parent material, therefore, is the key to selection studies. The base population is made up of local materials, exotic materials, and improved families and populations. To constantly improve the base populations, we produce cyclical combinations, which help to obtain a high frequency of genes as well as conserve high genetic variability.

SELECTION CRITERIA

The main objective of the selection program and plant breeding is to produce sweet potato varieties with high yields of dry matter per unit of time and area in a monocultural system, and with high resistance to diseases and pests.

Productivity and resistance to virus disease, therefore, are the first criteria of selection. Rwandan farmers, however, appreciate tubers of good quality, rich in starch, and having good taste. With regard to the vegetative cycle, early-maturing varieties (4 months) are preferred in the first season to enable additional crops to be grown in coming seasons. They allow, therefore, two crops per year. Also, the fast-growing varieties are particularly suited to low-altitude regions with irregular and low rainfall.

Nevertheless, the early-maturing clones are very sensitive to weevils during the dry season. This is the reason why the relatively late-maturing clones, which are vigorous and hardy, are preferred for the second crop, which is planted at the end of the dry season.

The qualities of taste, nutritive value, and rapid growth are considered as the second, third, and fourth criteria of selection. Results over the last 5 years (1978-1983) have shown that the productive clones are adapted to specific ecological areas. Few varieties are widely adapted to all three of the main ecological zones of the country. As mentioned earlier, even though the sweet potato is an adaptable crop it suffers from cold at high altitudes, hydromorphy in swampy areas, and drought in the low-altitude regions. The adaptability of the sweet potato, therefore, to different types of environment is the last criterion for selection but by no means the least. Table 3 outlines the selection procedure followed.

RESULTS

Selection

The program of selection and identification has identified, from the varietal comparative yield trials conducted in the three main ecological zones of Rwanda, some varieties that are adapted to low-, mid-, and high-altitude regions of the country. Table 4 shows the yields and other important characteristics of the best varieties.

Currently, trials are being conducted in such a way that all of the best materials are put in one trial to help judge production stability over a number of seasons. Some of the best clones have shown a correlation between yield of fresh tubers and dry weight of tubers (r=0.66) and between the weight of the cuttings and the percentage of dry matter in the tubers (r=0.50). The growth of aerial parts contributed to the formation of dry matter. The varieties with big tubers tend to have the highest yield of dry matter (r=0.55).

Agronomic Techniques

Planting Method and Density

The practice of planting trial cuttings on ridges, bunds, and level areas was compared in 1977, 1978, and 1979 without showing any significant differences. However, the experiment conducted on spacing and population density, repeated for two seasons in 1979, showed that the interaction between varieties and population density is not significant and that small ridges of 50 cm height have a slight advantage over those 80 cm high.

Results also showed that population density based on three cuttings per hole did not differ from that resulting from a single cutting per hole. Also, the planting of pregerminated cuttings did not reveal any advantage over the planting of nonpregerminated cuttings.

Fertilizer

The trials on organic and inorganic fertilizers conducted in 1982 at 15 localities from 10 agricultural regions and involving various types of soils involved five clones of sweet potatoes (Rusenya, Caroline Lee, and three of the best adapted clones). Although moderate doses of inorganic nitrogen and potassium gave high yields in all localities, the application of manure as a mulch treatment in drier lowland areas at the rate of 35 t/ha gave yield increases up to 285%.

On-Farm Experimentation

Preextension testing and experimentation in farmers' fields is only being carried out close to the research stations of ISAR. This will change, however, in the future and different ecological conditions and soil types will be taken into consideration in various localities.

Table 3. Sweet potato selection procedure in Rwanda.

Timing	Selection stage	Population density	Experimental procedure	Selection criteria	Selection intensity
1st year					
August	Germination	10000 seeds	Incubation at 30°C	Germination	
August	Nursery	10000 seedlings	Nursery beds, 30 m x 1.2 m; spacing, 10 cm x 10 cm	Virus diseases, fungus diseases	
November	Selection field	10000 clones	Families divided into four replications; square pattern of 100 clones; two cuttings per hole/clone	Virus and fungus diseases, weevils	5% from each 100 clones
May	Clonal evaluation in swampy (dry season) area	500 clones	Test involves four clones and one replication; plot, 1.8 m x 0.8 m	Virus and fungus diseases, weevils	50%
2nd year					
October	Preliminary yield trials (1st season)	250 clones	Test involves four clones and one replication; plot, 5.1 m x 0.80 m	Yield, virus diseases, fungus diseases, weevil pests	40%

March	Preliminary yield trials (2nd season)	100 clones	Test involves four clones and one replication; plot, 5.1 m x 0.80 m	Yield, virus diseases, fungus diseases, weevil pests	
3rd year	Sorting trials at three stations (two seasons)	100 clones	Test involves four clones and one replication; plot, 5.1 m x 0.8 m	Yield, virus and fungus diseases, weevil pests, drought, cold, adaptability to environment	15%
4th and 5th years	Multilocal varietal comparative trials (four seasons)	15 clones	Randomized blocks with four replications; plot, 5.1 m x 0.80 m	Yield, virus and fungus diseases, weevil pests, drought, cold, adaptability to environment	30%
5th year	Preextension	4 clones	Simple repetition across peasant farms	Yield, taste, plus criteria established by farmers	

Table 4. Performance (t/ha) of the best varieties from multilocational varietal trials, 1980-1982.

Ecology Varieties	Origin	Mean annual yield 1980	Mean annual yield 1981	Mean annual yield 1982	Mean yield (1980-1982)	Susceptibility to diseases and pests	Other characteristics
Low altitude (800 - 1200 m)							
Nyiramujune[a]	Local	10.0	13	11	12		
Nenyakanige	Local	12.7	-	-	12.7		
Nyirakayenzi	Local	9.3	-	-	9.3		
Caroline Lee[a]	Zaire	-	15.5	9.8	12.7		Carotene, very fast maturing
Gahungezi[a]	Local	9.6	-	-	9.6		
Caroline Lee 1666	ISAR	-	21.8	7.7	14.8		
TIS 2544	IITA	-	18.3	7.1	12.7	Weevils	Early maturing
TIS 2498/16	ISAR	-	-	10.3	10.3		Carotene, early maturing
Rusenya	Local	-	13.3	3.2	8.3	Very resistant to virus diseases	Well adapted
Mid-altitude (1200 - 1900 m)							
Rusenya[a]	Local	26.5	23.5	16.2	22	Very resistant to virus diseases	

Nsasagatebo[a]	Local	17.9	-	-	17.9		Early maturing but requiring good soil
Anne-Marie	Local	-	23.5	14.5	19	Virus diseases	
6634 Cordes Rouges	Zaire	26.1	18.5	5.9	16.8	Mites	Bad shooting in early stage
Cordes Vertes	Zaire	-	20	-	20		
TIS 2544	IITA	-	19.3	8.4	13.9	Weevil pests	Very fast maturing (3 months)
Neulira 1026	ISAR	-	18.0	13.0	15.5		
Caroline Lee[a]	Zaire	-	16.8	9.5	13.2	Weevils semi-vigorous	Very fast maturing
Di. Virosky 16/820	ISAR	-	-	12.8	12.8		Carotene, early maturing
Red Jersey 1220	ISAR	-	-	13.6	13.6		Early maturing
Bukarasa 812	ISAR	-	-	14.1	14.1		
Bukarasa	Local	20	18.5	-	19.3		
Nyiramujuna	Local	23.5	-	-	23.5	Anthracnose	

continued

Table 4. Performance (t/ha) of the best varieties from multilocational varietal trials, 1980-1982 (cont'd).

Ecology Varieties	Origin	Mean annual yield 1980	Mean annual yield 1981	Mean annual yield 1982	Mean yield (1980-1982)	Susceptibility to diseases and pests	Other characteristics
High altitude (1900 - 2300 m)							
Nasagatebo[a]	Local	17.7	-	-	17.7		Early maturing, requiring good soils
Di. Virosky 16	Zaire	14.8	-	-	14.8	Weevils	Early maturing
Rusenya	Local	14.2	12.0	10.7	12.3		Adaptable, late-maturing variety
Anne-Marie	Local	-	14.8	13.6	14.2	Virus diseases	Fibrous cortex
TIS 2498/16	ISAR	-	-	17.3	17.3		Early maturing
TIS 2544	IITA	-	10.2	16.6	13.4		Early maturing
Di. Virosky 16/820	ISAR	-	-	15.0	15.0		
Red Jersey 1220	ISAR	-	-	14.2	14.2		Early maturing
Caroline Lee[a]	Zaire	13.0	9.3	12.5	12.6	Weevils	Fast growing
Rutambira[a]	Local	-	-	12.6	12.6	Resistant to virus diseases	Late maturing
Bukerasa	Local	16.4	-	-	16.4		

[a] Released varieties.

Three or four of the best varieties from varietal yield trials and one or two of the most promising agronomic techniques are combined for on-farm trials. Each variety consists of a single replication on a ridge and on a bund, which enables the comparison to be made with varieties and methods utilized by the farmers. The area per plot is about 16 m^2.

Land preparation is carried out by the farmer, whereas other activities are carried out by both the farmer and researcher. At the farm level, fertilizer is not used. Weeding operations are normally carried out after a period of 1 month. Observations are made by the researcher along with the farmer and harvesting takes place after 5 months. The results obtained indicate that planting on ridges is more advantageous than planting on bunds, the yields being 16 and 13.7 t/ha respectively.

The five best clones for regions of low altitude were tested in 1980 at six farms within the area. The early-maturing Caroline Lee (23 t/ha), Rusenya (14 t/ha), and Cordes Rouges (12.5 t/ha) proved to be very well suited to the conditions on the farms. Each of the tested varieties was chosen for a specific characteristic: Cordes Rouges for its consistency; Rusenya for its taste; and Rusenya and Caroline Lee for their colour (high content of carotene). Similar results obtained in 1982 from all over the country confirmed that Rusenya and Caroline Lee varieties are very adaptable. Nyiramujuna and Nyiranjonjyo, on the other hand, gave good results only in regions of low altitude and Rutambira in regions of high altitude.

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STRATEGIES FOR ROOT-CROP IMPROVEMENT IN UGANDA

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Root crops, particularly cassava (*Manihot esculenta* Crantz.) and sweet potatoes (*Ipomea batatas*), play a significant role in the economy of Uganda. Other crops, such as yam (*Dioscorea* spp.) and cocoyam (*Xanthosoma* spp. and *Colocasia* spp.) are also grown, especially in Buganda and Western regions, but their importance is relatively minor. Irish potatoes (*Solanum tuberosum*) are important only in the highland areas of Kigezi and Sebei.

Although the presence of cassava in East Africa was recorded as early as 1779 in Zanzibar (Grant 1875), cassava did not reach Uganda until the end of the 19th century. The Speke and Grant expedition of 1862 did not report the presence of the crop further north than latitude 4°18'N but Stanley found it growing in 1870 (Grant 1875). Morgan, speaking in 1912, states that cassava was widely cultivated in Uganda and that its value as a reserve against the risk of famine was quickly appreciated (Simpson 1918, 1926). The crop is gradually replacing sorghum and finger millet as a staple food crop (IDRC 1982).

Cassava is grown throughout the country but the greatest production comes from the Northern and Eastern regions. Of the 2.35 million metric tonnes of cassava produced in Uganda in 1974, 0.92, 0.68, 0.42, and 0.35 million metric tonnes were produced in Northern, Eastern, Western, and Buganda regions respectively (Planning Unit 1975). Much of the cassava is cropped with maize, beans, and groundnuts, which are harvested at maturity, usually 3-4 months after planting, thus leaving pure stands of cassava. Cassava is grown by peasant farmers in small plots of not more than 1 ha each, although large fields of cassava are beginning to emerge. The area under cassava, by region, is shown in Fig. 1.

Cassava is used mainly for human consumption; however, in some parts of the country, especially in Lango, Acholi, and Teso, *enguli*, an important local alcoholic drink, is distilled from dry cassava tubers. This has indicated that pure alcohol can be distilled from cassava relatively cheaply. Starch is also manufactured from cassava tubers by the Lira Starch Factory in Northern Uganda.

Research on root crops, especially cassava and sweet potatoes, is being conducted at Serere Agricultural Research Station under the Ministry of Agriculture and Forestry. The station is situated at latitude 1°31'N, longitude 33°27'E and at an altitude of 1140 m above

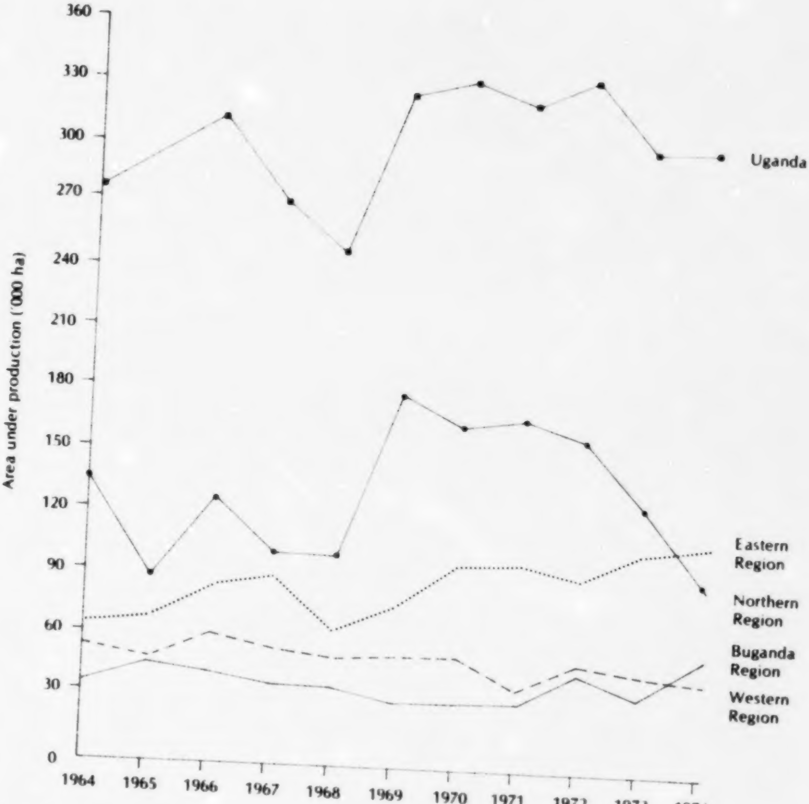

Fig. 1. Area under cassava, 1964-1974.

sea level. In these areas, farmers require cassava and sweet potato varieties that give high and reliable yields. The station is located in an important cassava and sweet potato growing area and is served by a network of government variety trial centres (VTCs) (experimental substations) scattered throughout all ecological zones of the country. At the VTCs, research materials are tested without charge to the crop improvement programs that make use of this service.

Research on sweet potatoes was conducted at Kawanda and Serere Research Stations and Makerere's university farm, Kabanyolo, during pre-Independence and shortly after Independence. The work was mainly concerned with evaluating common local and a few introduced varieties for their yield and for resistance to and cultural control of the sweet potato weevil (Cylo spp.). This work was abandoned shortly after Independence after significant progress had been made.

The history of research on cassava in Uganda dates as far back as 1935. This work was based mainly at the then East African Agricultural Institute, Amani, Tanzania, where breeding of cassava for resistance to African cassava mosaic disease was being carried out. Materials developed at the institute were evaluated further at Serere Research Station and at other places in Uganda for resistance, adaptability, and good agronomic attributes. As a result, a number of varieties (Serere and Bukalasa lines) were released to farmers for growing and the work was abandoned in the late 1950s.

With the outbreak of the cassava green spider mite *Mononychellus tanajoa* at Kampala in 1971, cassava research in Uganda was revived. This was based on entomological investigations of the distribution in Uganda, biology, ecology, and control of the green spider mite. The work was based at Kawanda Research Station, Kampala, and was later abandoned in the late 1970s after significant progress had been made.

At the discovery of the presence of cassava bacterial blight in Uganda, cassava research elsewhere in Uganda was transferred to Serere Research Station and the program was expanded to include plant pathological investigations, with emphasis being placed on cassava bacterial blight and African cassava mosaic disease. In 1980, the program was upgraded to the National Root Crops Improvement Programme (UNRCIP) and assigned the responsibility of improving production and utilization of root crops, especially cassava and sweet potatoes, in Uganda. A plant breeder, an agronomist, and a food technologist were then posted to the core program at Serere. The program is headquartered at Serere Research Station and involves all disciplines: a plant pathologist, breeder, crop entomologist, agronomist, and food technologist are all present. All of these disciplines are responsible to the program leader, who coordinates all of their activities and, in consultation with the Director of Research and the Commissioner for Agriculture, directs research efforts to areas that need urgent attention. Research experiments conducted the previous year are reviewed and new proposals for the coming year are discussed for approval or rejection at the annual national experiment committee meeting (ECM), which is attended by all research officers, directors of research stations; the Commissioner for Agriculture; the Dean of the Faculty of Agriculture and Forestry, Makerere University; and a representative from the National Research Council, farmers, Lint and Coffee Marketing Boards, and regional agricultural officers. Projects approved at the ECM are further discussed at the annual agricultural advisory committee meetings, the main policymaking body of the Research Division.

The National Root Crops Improvement Programme enjoys close working relationships and exchanges research experiences, results, and inputs with the rest of the research programs at Serere Research Station; with the Ministry of Regional Co-operation's Sorghum and Millets Unit at Serere; and with the other research programs at Kawanda and Namulonge Research Stations and at the Faculty of Agriculture and Forestry, Makerere University, Kampala. Close cooperation in the form of the exchange of improved materials, technologies, and information and visits and training also exist with the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia; and the Asian Vegetable Research and Development Center (AVRDC), Taiwan.

PROGRAM OBJECTIVES

Broad Objectives

The immediate overall objectives of the Uganda National Root Crops Improvement Programme are to evaluate the existing root crop varieties and husbandry practices in Uganda in terms of their benefits to the farmer and to develop improved high-yielding varieties and husbandry practices that will increase those benefits to the farmer. These objectives were established based on the fact that improved crop technologies could only be successful if they were developed based on knowledge of the performance and limitations of existing local varieties, husbandry practices being followed by farmers, farmers' circumstances under which crops are being grown, and how these can be improved.

Specific Objectives and Methods of Achieving Them

The specific objectives of the program are:

(1) To survey a sample of cultivators who grow a substantial amount of root crops, especially cassava and sweet potatoes, in selected areas of Uganda: Initially, the program was to concentrate on the Eastern, Northern, and Nile regions of the country. These are the areas of greatest root-crop production. Approximately 10% of the villages in the project area are chosen, area by area, to provide good coverage of the total target zone. Ten households are chosen from each village, selecting those that regularly grow a substantial amount of crops. Exploratory surveys are conducted by the research scientists through questionnaires. The questionnaire includes the following information: (a) number of cultivars grown with approximate area of each, soil types, names of varieties grown, maturation period and sweetness or bitterness of varieties, scores for individual pests and diseases, yield estimates, and uses of varieties; (b) planting times and methods, previous crops and manure/fertilizer treatment on current crops, land preparation, ridge or flat seedbed, whether intercropped and with what, weeding frequency, and harvesting method and whether part or the whole field is harvested at once; and (c) proportion of the crop used for domestic consumption or for sale and how sold. Collections were made of all cultivars grown by the farmers surveyed.

(2) To evaluate the materials collected from farmers: A nursery was planted with cuttings from all of the farmers' cultivars collected during the survey. The cultivars were interplanted with pest and disease susceptible materials previously inoculated/infected or infested with the appropriate organism(s). The cultivars were later evaluated for pests, disease resistance, and good agronomic qualities. The best entries were multiplied and planted in yield trials at several locations, grouped by duration and soil types. The best entries were again multiplied for further testing and as a source material for multiplication and distribution plots. They also form the elite of local clones as a reference base.

(3) To improve root-crop cultivars: The surveys identified pests and diseases, i.e., cassava bacterial blight, *Xanthomonas campestris* pv. *manihotis*; African cassava mosaic disease; cassava anthracnose, *Colletotrichum* spp.; cercospora leaf spots, *Cercospora* spp.; and the cassava green spider mite, *Mononychellus tanajoa*. Appropriate resistant materials have been obtained from IITA and used as parents in crosses with the elite, adapted local lines identified during the evaluation. Segregating generations were screened for resistance to appropriate diseases/pests and for bitterness. Yield trials were conducted using farmers' cultivars as controls and under good husbandry practices; dry matter yield, starch content of tubers, and yield potential are important at this stage. These were repeated

across locations and the best entries identified for yield, resistance, and tuber quality were subjected to farmers' trials.

(4) To broaden the germ-plasm base: A collection of cassava and sweet potato germ plasm from various parts of Uganda has been established. To this collection will be added introductions from IITA and elsewhere. The most promising selections from segregating progenies will be added to the collection.

Husbandry Practices

The practices of the best cassava and sweet potato farmers, as established during exploratory surveys, were taken as the baseline and modified. Those that seemed to produce superior results in field trials were incorporated into farmers' trials and evaluated by them.

Plant Pathology

To identify diseases affecting cassava and sweet potatoes in Uganda, surveys were carried out throughout the country and experiments were conducted at selected VTCs in different ecological regions. Diseased plant samples are sent to the Commonwealth Institute of Mycology (CMI) for identification.

To screen cassava varieties for resistance to African cassava mosaic disease, cassava bacterial blight, cassava anthracnose, cassava stem rust, bacterial stem gall, and cercospora leaf spot, screening methods developed at IITA will be adopted.

To study pathogenic variations among cassava bacterial blight pathogen Xanthomonas campestris pv. manihotis and adopt appropriate strategies for screening varieties for resistance to the disease, samples of infected cassava leaves and stems will be collected from various regions of Uganda. The bacteria will be isolated from each sample and standard doses of the isolates made. These will then be used to inoculate cassava seedlings in the greenhouse. The ability of each isolate to induce disease and to what degree of severity will be established.

To screen sweet potatoes for resistance to the sweet potato virus complex, the tissue-implantation method commonly used at IITA will be adopted.

Crop Entomology

To identify important cassava and sweet potato pests and screen varieties/lines for resistance to them, pest surveys will be carried out throughout Uganda and field experiments conducted at VTCs located in the various ecological regions. The population buildup of the major pests will be followed and the economic status of the pests assessed.

To screen for resistance of cassava varieties to the green spider mite, the method based on scoring for mite infestation on a scale of 0-5 (as described later) is used. As well, the applicability in Uganda of any IITA-developed cultural or biological methods of controlling the green spider mite will be tested at Serere Research Station and in selected farmers' fields.

To screen for resistance to the sweet potato weevil, sweet potato tubers will be assessed on a scale of 0-5 for weevil infestation.

Evaluation Methods

The methods for evaluating germ plasm for resistance to pests and diseases and for plant and root characteristics are presented in Tables 1 and 2. Each method, using a score of 0-5, is based on a visual estimation of the severity of disease infection or pest infestation and on the degree of intenseness of plant and root characteristics. This method has the advantage of being simple, quick, easy to use, and does not require a lot of skill.

Multilocational Tests

Promising germ plasm of cassava and sweet potatoes is evaluated at selected VTCs that represent the different ecological regions of the country. A network of over 40 VTCs was established during the colonial period to provide areas for testing the technologies developed at research stations for their suitability in the areas concerned. Each VTC is headed by a varietal trial observer (VTO) who usually has a diploma in agriculture. The VTO is supported by agricultural and field assistants. The VTOs are supervised by the officer in charge of the VTCs, who reports to the coordinator of the VTCs, usually a research agronomist appointed by the Commissioner for Agriculture.

On-Farm or Village Tests

The Research Division of the Department of Agriculture has not embarked upon on-farm or village tests; however, plans are under way to incorporate them into the research system.

Quality Tests

Testing the quality of cassava and sweet potato tubers involves counting the number of marketable and unmarketable tubers and estimating the percentage dry matter, starch content, and bitterness of the tubers. The dry matter content of the tubers is determined by taking 2-kg samples of fresh tubers and drying them to a constant weight at 105°C for 4 days. The starch content of the tubers is estimated using the specific-gravity method. This involves determining specific gravities of samples of tubers and reading their percentage starch contents from a standard graph. Bitterness of the tubers is based on organoleptic tests scored on a scale of 1-5, as described in Table 2.

SUMMARY OF METHODOLOGICAL ISSUES

The current objectives of the program have changed considerably. In the past, it had been assumed that technologies developed at research stations would be directly and immediately adopted by farmers. Experience has shown, however, that this assumption has been incorrect and that most of the technologies have not been easily adopted by farmers. As a result, there has been a reexamination of the strategy and it has been realized that development of easily adoptable crop technologies can only be achieved based on a sound understanding of the limitations of existing crop varieties and husbandry practices followed by farmers and on an understanding of farmers' circumstances.

It has also been realized that for a technology to be easily adoptable, the people who will eventually use it should be allowed to

Table 1. Methods of evaluating cassava and sweet

Disease or pest score	CBB	CMD	CA	LS
0	No leaf spot, leaf blight wilt, or dieback on stems	Apparent field resistance, no symptoms seen	No lesions on stems, petioles, or leaves	No symptoms of leaf spot
1	Very few angular water-soaked leaf spots with occasional leaf blights	Mild chlorotic pattern over entire leaflets or very mild distortions only at the base of leaflets, with the remainder of the leaf appearing green and healthy	Few small lesions can be seen on stems and petioles	Few leaf spots on leaves. Approximately 2% of leaf infected and destroyed
2	Angular leaf spots and leaf blights are predominant. No defoliations or gum exudations on leaf lamina, petioles, or stems	Mild chlorotic pattern over entire leaflets or mild distortions only at base of leaflets, with the remainder of the leaf appearing green and healthy	Few yellowish cankers on woody stems late in the season	Many leaf spots on leaves and approximately 4% of leaf infected and destroyed
3	Abundant angular leaf spots and blights; yellow gum exudation on lamina petioles and stems; moderate leaf and twig wilt; and defoliations but no tip dieback	Strong mosaic pattern all over the leaf; narrowing and distortion on lower one-third of leaflets	Large numbers of deep cankers on woody stems followed by distortion	Very abundant leaf spots and approximately 8% of leaf infected and destroyed
4	Very abundant angular leaf spots and blights; yellow gum exudations on stems, petioles, and lamina; very severe leaf and stem wilting; and defoliations together with tip dieback and wilting of lateral branches	Severe mosaic pattern; severe distortion of two-thirds of leaflets; and general reduction of leaf size	Large number of oval lesions on green stems	Severe leaf spotting; leaf spots coalesce together in some cases; and approximately 13% of leaf lamina infected and destroyed
5	Very severe and extensive dieback and drying of most of the green parts of the stems leading to occasional death of the plant	Severe mosaic; severe distortion of four-fifths or more of leaflets; twisted and deformed leaves; and severe reduction of leaf size	Large numbers of lesions; severe necrosis of leaf axils; followed by wilting and severe defoliation	Very severe leaf spotting; leaf spots coalesce in most cases; and approximately 31% of the lamina infected and destroyed

Note: CBB = cassava bacterial blight; CMD = African cassava mosaic disease;
CSR = cassava stem rust; RR = cassava root rot; SPVC = sweet potato

potato germ plasm for resistance to pests and diseases.

CSR	RR	SPVC	GCM	SPW
No rust pustules on mature stem	No tubers rotted	No symptoms of virus on leaves	Apparent field resistance. No spots on terminal buds and leaves are free from mites	Tuber free from weevil infestation
Very few rust pustules on mature stems	Very few tubers rotted	Mild chlorotic patterns or vein clearing on leaf	Mites present and few white spots on terminal buds and on young leaves	Localized swellings on stems and holes on root neck. Less than 10% of tubers weeviled
Rust pustules are abundant on mature stems	Few tubers rotted	Vein clearing, mottling, and distortion of leaves	Few whitish spots on young unfolded and first expanded leaves	Localized swellings on stems; holes on root neck; and 20-40% of tuber weeviled
Rust pustules overcrowded and very abundant on stems	Half the number of tubers rotted	Pronounced vein clearing, mottling, distortion, strapping, and chlorosis of the leaves	Shoot leaves not fully expanded, older expanded leaves with distinct chlorotic spots, and leaf size reduced by about 25%	Localized swellings with severe rotting of stem; 40-50% of tuber weeviled
Overcrowding and excessive abundance of pustules; stems start becoming very rugose	Severe rotting of tubers	Very pronounced vein clearing, mottling, distortion, strapping, and chlorosis of the leaves. Some stunting of plants can also be observed	Apical leaves not expanded; reduction of leaf size to more than 50%; severe chlorosis on older leaves; and possibly infestation of oldest leaves	Localized swellings and severe rotting of stems; 60-80% of tubers weeviled and rotted
Overlapping of most of the pustules that are already excessively abundant on matured stems. Stems completely rugose; withering and death of some lateral buds	All tubers rotted	Very pronounced vein clearing, mottling, distortion, strapping, and chlorosis of leaves; very severe stunting of plants	Shoot dead or unproductive; older leaves infested; little or no infestation of lower expanded leaves	Severe rotting of stems and over 80% of the tuber is weeviled and rotted

CA = cassava anthracnose; LS = cercospora leaf spots of cassava;
virus complex; GCM = cassava green spider mite; SPW = sweet potato weevil.

Table 2. Methods of evaluating cassava and sweet potato germ plasm for plant and root characteristics.

Plant or root score	CS	BH	PC	LH	TNL	TSC	TSZ	TGA	TS	TB
1	Very poor	Very poor (0.1–0.25 m)	Brown	No hair	Short/no neck	Brown	0.5 kg	Very poor	Round	Very sweet
2	Poor	Poor (0.25–0.5 m)	Dark brown	Trace	About 5–7 cm	Dark brown	0.5–1 kg	Poor	Oval	Sweet
3	Average	Average (0.5–1.0 m)	Purple	Average	About 7–10 cm	Purple	1–2 kg	Medium	Medium long (desirable)	Average
4	Good	Good (1–1.5 m)	Red	Abundant and long	About 10–15 cm	Red	2–5 kg	Good	Very long and fat (desirable)	Bitter
5	Very good	Very good (above 1.5 m)	White	Very abundant and long	>15 cm	White	≥5 kg	Very good	Very long and thin (undesirable)	Very bitter

Note: CS = plant's canopy/structure; BH = plant's branching habit; PC = petiole colour; LH = leaf hairiness; TNL = tuber neck length; TSC = tuber skin colour; TSZ = tuber size; TGA = tuber general appearance; TS = tuber shape; TB = bitterness of tubers.

evaluate it before it is released to them. Consequently, the current program places more emphasis on on-farm testing of research station generated technologies. Plans are under way to establish village or on-farm testing networks to fulfill this need. Past evaluation of research station generated technologies was mainly restricted to VTCs. The new networks will be the most innovative and interesting feature of the program.

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FARMING SYSTEMS RESEARCH METHODOLOGY: THE MOROGORO EXPERIENCE

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The farming systems research (FSR) approach, used to accelerate agricultural development, has only recently been adopted in many developing countries. The Morogoro project began during the March/April 1981 cropping season but the approach is still in its infancy stage of implementation within Tanzania. This paper reports briefly on the experience gained to date by the University of Dar es Salaam Faculty of Agriculture.

SITE LOCATION (NORTHERN PLAINS OF MOROGORO DISTRICT)

The project is being carried out in the Northern Plains of Morogoro District, a large lowland zone in which most of the farmers have experienced similar problems, potentials, farming activities, social customs and background, and market opportunities. The zone has an average altitude of 400-600 m above sea level and experiences a bimodal rainfall pattern ranging from 700-1000 mm. The short rains usually begin in late October and end in late January. The long rains last from early March to late May, peaking in April. This rainfall pattern dictates how land can be used and, hence, the choice of the crop. Sorghum has the reputation of being able to withstand droughts when they occur and is the staple food crop of the area.

The soils in the zone are mainly clay loam or sandy clay loam varying in colour from dark grayish brown to red. Other crops grown in addition to sorghum include maize, pulses (cowpeas and grams), oilseeds (sunflower and simsim), and cotton, with rice and bananas being grown in the river valleys. Preliminary surveys indicated that there was considerable potential for the development of sorghum.

PHYSICAL-SOCIAL-ECONOMIC ENVIRONMENT

The two villages of Melela and Mangae, selected for the FSR project in the Northern Plains, have similar socioeconomic characteristics. Both villages are inhabited by the same tribe; they are situated along the Dar es Salaam/Zambia main road and, hence, are easily accessible from the Morogoro campus; the supply of drinking water is adequate (although not necessarily convenient to all inhabitants); both have a primary school, which offers evening adult-education classes; and each has at least one shop. The only shop at Melela is owned communally by the villagers. Medical services are only available at Melela.

PROJECT OBJECTIVES

The overall project objectives are to increase crop productivity and the welfare of the small-scale farmers in the district, test the appropriateness of the FSR methodology, and demonstrate the benefit of the FSR approach in the development of technology relevant to smallholders in the district and in Tanzania at large.

The specific objectives of the FSR project at Morogoro are to study the present farming systems in Morogoro District and identify constraints to increased food crop production, test new technologies through adaptive research experiments with farmers, evaluate the suitability and acceptability of these recommended technologies, and train BSc and postgraduate Tanzanians in the concept and methodology of FSR.

FSR METHODOLOGY

Implementation

The staffing pattern for the project is illustrated in Fig. 1.

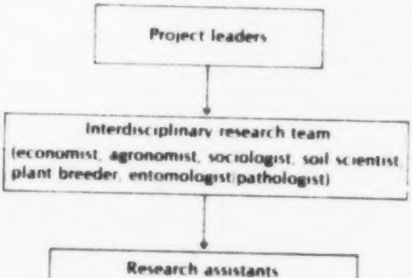
Project leaders
Interdisciplinary research team
(economist, agronomist, sociologist, soil scientist, plant breeder, entomologist/pathologist)
Research assistants
(BSc Agric)
Field assistants
(Agricultural Certificate holder)
Two village assistants
(Class Seven education level)

Fig. 1. Organizational structure of the FSR project.

The framework for FSR and development, as developed by the Morogoro interdisciplinary FSR team, consists of site selection, site description, cropping-pattern design, testing, multilocation testing, and, eventually, production-program formulation (Fig. 2).

A diagnostic survey of the study area revealed that cereals (mainly sorghum but also maize) and legumes are the major crops in the area. Common legumes include beans, cowpeas, green gram, and pigeon pea. They can be found growing either singly or mixed (intercropping). The following were identified as the major production constraints: poor crop management practices, such as the use of low plant populations and late or nonexistent weeding; continued use of traditional/local seed varieties for both cereals and legumes; problems with pests and diseases; moisture stress due to unreliable rainfall; and postharvest losses.

Based on this information, a number of hypotheses were formulated that are now being tested. These hypotheses include: (1) low sorghum plant population per unit area contributes to the observed low yields; (2) late thinning causes early plant competition, resulting in low crop yields; (3) poor weed-control practices contribute significantly to the low yields of sorghum and other crops grown in the area; (4) deeper cultivation techniques can reduce the impact of weeds on the early development of the crop; (5) excessively deep sowing of the seed hinders proper and healthy germination, which may then contribute to the observed low yields; (6) earthening up of plants at weeding could influence stalk development (and possibly the tillering pattern) and, consequently, yield; (7) late planting (or off-season planting) may be the cause of yield variation, thus the need to identify the proper planting date for any cropping season; (8) exploitation of nutrients/nitrogen from weeds could be achieved by incorporating them into the soil during weeding; (9) the impact of bird damage on sorghum yields could be minimized by using adequate bird control measures; and (10) introduction of short-season high-yielding sorghum varieties could have a tremendous effect on the yield of the crop; hence, the adaptability and acceptability of varieties of this kind should be tested.

The initial experiments conducted during the 1981 cropping season only looked at three variables that were considered to have an immediate impact on sorghum grain yield. These were plant population, weeding, and the introduction of early maturing seed varieties in the study area. The study of these variables provided further information for the formulation of other experiments in the project. The exact experimental results and details of their methodology can be obtained from the annual reports for the project.

Choice of Farmers and Management of Experimental Materials

Farmers were obtained on a voluntary basis through consultation with the village administrators (Fig. 2). Meetings in the villages were arranged by the respective village chairmen, at which the project leader(s) and principal researchers (Fig. 1) explained to the prospective participants what the project was about and outlined the experiments for the season. It was only after such meetings that those interested farmers who felt convinced of the merit of the project registered with the village assistants or field assistant. The exact number of farmers recruited in any one cropping season depended on how many farmers were interested.

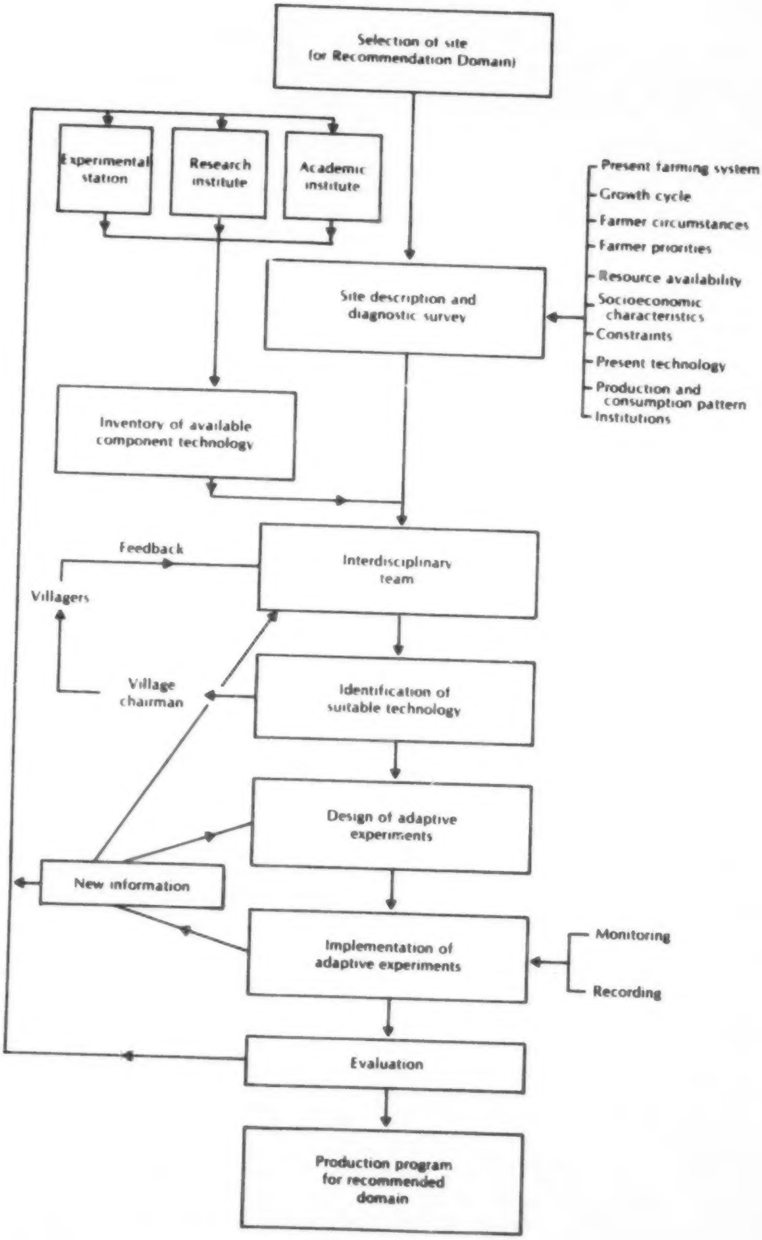
Selection of site (or Recommendation Domain)
Experimental station
Research institute
Academic institute
Present farming system
Growth cycle
Farmer circumstances
Farmer priorities
Resource availability
Socioeconomic characteristics
Constraints
Present technology
Production and consumption pattern
Institutions
Site description and diagnostic survey
Inventory of available component technology
Feedback
Villagers
Interdisciplinary team
Village chairman
Identification of suitable technology
Design of adaptive experiments
New information
Implementation of adaptive experiments
Monitoring
Recording
Evaluation
Production program for recommended domain

Fig. 2. Farming systems research methodology.

After the experiments are designed, seeds are provided to the farmers free and whatever seed yield is realized from the experiments is given back to the farmer after the necessary data have been collected and yield measurements have been made.

On a day-to-day basis, data are collected by the field assistant and the two village assistants in their respective villages. The field assistant resides in one of the villages (Mangae) in a house built using FSR funds. The village assistants stay in their own houses.

The research assistants and principal researchers (on the interdisciplinary team) visit the sites on a regular basis and when the need arises, e.g., sowing or harvesting time.

The school sites in both villages in the Northern Plains have been used in the project to complement experiments conducted with individual farmers. The assumption is that if the children can learn from the technology tested in the FSR approach to crop production methods they can then be regarded as "potential ambassadors" to their parents or other farmers in their villages or "future farmers," as most children in such village schools usually go back to live with their peasant farmer fathers after completing their primary education.

Problems Encountered in the FSR Project

Vermin and bird attack has always been a serious problem on the new sorghum variety plots. Attack by wild pigs usually occurs when the plant is at the milky stage. Devastation has been total at times but depends on the distance between the homestead and the experimental plots.

Similarly, bird damage, occurring almost simultaneously with the attacks of the wild pigs, has continued to plague the early varieties. Researchers have been flexible in redesigning experiments to cater to unforeseen problems, e.g., the use of paper bags to cover sorghum heads. Half of the experimental plot is covered by such bags and half is left open to bird attack. This enables an assessment of bird damage under natural conditions to be made. Also, the use of traps and thorn hedges to prevent wild pigs from entering the experimental plots have met with some success.

Problems have also been encountered with respect to storage. Hybrid sorghum seed does not store very well and the problem may only be solved through incorporation of this additional criterion during breeding.

Some of the farmers (especially during the initial stages of the project) tended to harvest their plots without the knowledge of the field staff, which created difficulties in estimating yield data.

Some labour-intensive activities, such as charcoal burning, sometimes contributed to the observed labour shortage at critical periods, especially at weeding time, and accounts for some of the compromises made by farmers in their agronomic practices.

Initially, money had been paid for the labour provided to maintain a "clear-weeded plot" in a weeding experiment (i.e., researcher-managed experiment). Some farmers, however, requested payment for any services rendered for other experiments in the project (i.e., farmer-managed trials). When such requests were refused, the farmers refused to cooperate and abandoned the experiments in their plots. After consultation with the farmers, however, this problem has now been solved.

When the interdisciplinary team was first assembled, some problems were encountered with respect to integrating the team members. This resulted in delaying the designing of new experiments and analyzing data from the previous cropping season. This problem is gradually being overcome.

BANANA-BASED CROPPING SYSTEMS IN UGANDA

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The edible banana is probably derived from the wild-seeded forms Musa acuminata and Musa balbisiana or is possibly a cross between the two (Simmonds 1966). It probably originated in Southeast Asia but the time and route of its introduction into East Africa is not clear. In Uganda, the crop is believed to have been brought into the country by the legendary ancestor of the Baganda people, Kintu, suggesting that the cultivation of bananas in Uganda extends beyond the written history of the country.

Today, the banana crop forms a large proportion of the diet of millions of Ugandans. It is estimated that more than 75% of the farmers grow bananas, with the crop occupying the largest cultivated area of all the staple food crops in the country. The banana is the staple food in the majority of the districts of Uganda. Simmonds (1966) also noted that Uganda was the largest producer of bananas for local consumption and that the domestic crop amounted to more than 15% of total world production.

In Uganda, four main categories of bananas are recognized: (1) the cooking banana, locally known as Matooke, forms the largest proportion of the bananas grown; (2) the roasting banana, locally called Gonja; (3) the beer banana, grown for producing a juice and a wine-like beverage and locally known as Mbidde and Kisubi; and (4) the sweet banana or dessert banana, locally known as Ndizi, Sukali, and Bogoya. Within these major categories there are distinct varieties. Traditionally, the crop is grown on small holdings, often less than 0.5 ha and invariably near homesteads. A typical grove of bananas comprises a mixture of varieties of cooking bananas and a few roasting bananas, the beer and dessert type being grown mostly on the outside of the main plantation. The crop is usually grown mixed in varying proportions with other crops. During the early stage of establishment, maize, beans, cassava, and groundnuts form the major intercrops with banana, whereas at later stages of growth other crops such as Dioscorea spp. taro, tannia, coffee, cocoa, and pineapple are usually interplanted.

In recent years, the hectarage under bananas has been increasing steadily. This is particularly true of the areas within 30 km of major cities. There are perhaps a number of reasons for this. Firstly, because of the growing urban population, the greatest proportion of whom feed on Matooke, the demand for Matooke has correspondingly risen. Secondly, the industrial alcoholic beverages have become unbearably expensive and the demand for them has, consequently, declined. The wine-like beverage (Mwenge) produced from bananas has, therefore, become an increasingly important alternative in the banana-growing zones. Thirdly, there is an increasing awareness among Ugandan farmers and traders of the demand for sweet bananas in the external market.

DEFINITION OF THE PROBLEM

The banana is known for imposing a great demand on the soil for its nutrients (Rimington 1964). In the past, the Ugandan farmer was partly able to overcome this problem by planting only on virgin fertile land and once the yields began to decline the farmer would establish another grove on a new piece of land. Because of the growing population pressure on land, however, this practice is no longer possible in most of the banana-growing zones. As a result, there has been a general reduction in soil fertility and increased disease and pest incidences. The most important of these are the banana weevil, nematode infestation, and sigatoka leaf spot and panama wilt diseases. In addition, there is generally poor crop management under the peasant situation, particularly with respect to plant density, weeding frequency, and planting time of the component species. Because of these factors, the yields from farmers' plots are low and are continuing to decline. The current banana yields in the country are estimated at 3.2-4.0 t/ha/year, which compares unfavourably with those of most banana-growing countries. In Honduras, for example, up to 30.4 t/ha/year are possible with high levels of inputs; whereas in one experiment carried out in Uganda, up to 16.2 t/ha was achieved (Nkedi-Kizza 1973), suggesting that there is considerable potential for improving banana yields in the country.

The Faculty of Agriculture at Makerere University, in collaboration with the Ministry of Agriculture, has recently proposed a research project on bananas. The aim of the project is to develop and test strategies for quickly increasing the yield of banana crops in farmers' plots. In this paper, some aspects of the methodology to be used in the study will be discussed. It should be emphasized at this stage that our problems are unique; unique in that we are virtually starting from scratch. Although the banana is an important staple food crop in Uganda, very little research effort has been devoted to the crop in the country.

OBJECTIVES OF THE PROPOSED STUDY

The general objective of the proposed banana-based cropping systems research at Makerere is to develop appropriate technologies aimed at increasing the productivity of the small farm holding. It has often been argued that farmers are sometimes reluctant to adopt recommendations because such recommendations may be inappropriate for them. This situation may arise because of the traditional research approach in which research goals are generally formulated within disciplines rather than between or among disciplines.

In the proposed research project, an interdisciplinary approach will be adopted and the research will be conducted both at the university farm, Kabanyolo, and on selected farmers' plots. The advantage of this approach is that it will establish the desirable link between the researcher, extension worker, and farmer, which is so often lacking in a traditional research approach. The overall objectives of the project will be: (1) to devise a means of economically controlling the decline in banana yields per unit area, and (2) to devise a means of improving the productivity of bananas and the component crops beyond present levels.

METHODOLOGY

Research Team

As mentioned earlier, the project will require a cooperative effort among disciplines. In other words, the project calls for an integrated approach in which there is constant interaction and feedback of information among participants. One essential requirement of such a team is that it should be small and comprise scientists who are willing to cooperate closely in carrying out the project. Each of the participants should be knowledgable in the discipline for which they will have primary responsibility. In this regard, our project will be made up of seven participants, which will include two plant pathologists, an agronomist, a soil scientist, an entomologist, a nematologist, and an economist/farming systems expert. Most of the participants have worked together as colleagues in the Faculty of Agriculture as lecturers and in various research programs and we feel, therefore, that they will cooperate in the proposed project. Because of the need to maintain a small and manageable team, we have, reluctantly, omitted a number of possible disciplines. For example, we have omitted a plant breeder, who is a key person in any crop improvement program. Our reasoning is that, at least during the initial phase of the project, we can manage without a plant breeder because we do not envisage any breeding work. The initial phase would also be utilized by the physiologist and agronomist to study and understand the crop and by so doing identify the desirable characteristics that can be incorporated by the plant breeder in a later phase. There is also a need to have a farm management economist, a biometrician, and a sociologist associated with the team. These, however, will be consulted when the need arises.

In addition to the above team, we propose to have seven research assistants hired on a full-time basis -- one for each discipline. These will be, preferably, BSc degree holders with some working experience in extension. They will assist during the survey and in carrying out on-farm trials.

Germ-Plasm Collection

To achieve our objectives, we feel that one of the immediate priorities is the identification of high-yielding banana varieties that will, at the same time, perform well under the farmer's situation. Because there has not been any serious research carried out in the country, the Ugandan farmer has not had the opportunity of growing some high-yielding varieties. Therefore, we plan to assemble a collection of banana varieties both within and outside Uganda. There are already a number of research centres carrying out some work on bananas, e.g., in Nigeria, the Philippines, and Jamaica. These countries, we believe, have some improved banana varieties that may be of interest to Ugandan farmers, although disease aspects may limit the use of germ plasm introduction.

We propose to explore the possibility of using tissue-culture methods, particularly for importing germ plasm from outside the country. As mentioned earlier, the initial phase will be used by the physiologist and agronomist to understand the crop and identify the desirable characteristics. Most important of these will be the growth habits, such as the number of suckers (tillers) per stool, height of the plant, size of the girth at different stages of growth, leaf size and arrangement, time to shooting, and bunch habits. The initial screening exercise will be carried out at the university farm, Kabanyolo. Because the Ugandan farmer traditionally grows bananas in combination with other crops, an important aspect of the screening exercise will be to assess how the different types respond to intercropping situations. The promising lines will then be tested under the farmer's situation on selected farms.

Farm Survey

As stated earlier, the primary objective is ultimately to be able to assist the small farmer in solving some of the numerous problems associated with banana production and, hence, improve the productivity of the crop. It is important, therefore, that the participating scientists be acquainted with these problems right from the initial stages of the project. In this connection, we realize that the farmer's own experiences can provide very useful guidelines in the process of identifying some of the problems. Thus, a baseline survey will be conducted to obtain systematized information on the common agronomic practices used by the farmer and other problems associated with banana production.

It is planned that sites for the baseline survey should be selected from those areas with the greatest concentration of bananas. These areas will include some parts of the Western region, the Lake Victoria crescent, and some parts of the Eastern region. Ecologically, these areas differ considerably, particularly with respect to soil types and the amount and distribution of rainfall. Thus, although banana is the main food crop in all of these areas, the component crops in the banana grove and even the cropping patterns differ from one region to another. In all, there will be six sites: Mbarara (Western region); Masaka, Mpigi, and Mukono (Lake Victoria crescent region); and Tororo and Mbale (Eastern region).

In this type of project, we consider a presurvey to be an essential exercise before a detailed farm survey can be conducted. This will simply involve reconnaissance visits to the selected sites with a view toward collecting background information that will then be used to design a questionnaire. It is planned to have at least one visit per site to acquaint the team with local problems. During such visits, informal discussions will be arranged with groups of farmers and agricultural officials of the area.

The team has not yet decided how to select the farmers to be interviewed in the detailed survey. There are some fears associated with using a completely random sampling procedure. One obvious problem with such a procedure is that it tends to give rise to an extremely heterogenous group of farmers, ranging from the illiterate to those who can read and write to the well-to-do. It appears, however, that the best approach will be to adopt the concept of "target groups" (Collinson 1980). In Uganda are what we often refer to as "progressive farmers." These are farmers who can generally read and write and who are rapidly responding to recommendations. We feel our sampling should be confined, initially, to this group of farmers. However, the exact details of how these are to be identified and how many will be sampled from each site will be finalized after the presurvey.

For the plant physiologist and the agronomist, the purpose of the survey will be to gain some understanding of the range of banana varieties grown, method of establishment, type of crop mixtures, planting arrangement and time of planting of the component species within a banana grove, and frequency and time of weeding. For the entomologist, plant pathologist, and nematologist, the purpose of the survey will be to identify the common pests and diseases affecting farm crops and make an estimate of yield losses due to the pests and diseases on the existing crop/crop mixtures to assist in determining the economic threshold level for subsequent control measures.

The soil scientist will determine the soil problems and, consequently, the remedial technological package the farmer needs to overcome the problems. In addition to the questionnaire, the soil scientist will take soil samples for analysis to assess the levels of the major nutrients. The economist will collect all relevant information in connection with resource utilization and costs of inputs and returns, as well as information on the marketing infrastructure, bottlenecks, and possible alternatives facing the farmer. Other information that will be of value will include the farmer's allocation of production and consumption preferences and existing customs and beliefs in relation to existing farming practices.

On-Farm Trials

It is estimated that the presurvey, design of the questionnaire, its implementation, and analysis of the data collected should be completed within 1 year. Based on the results of the survey, priority problems will be identified.

In addition, some farms will be selected on each site and these will be used for on-farm trials. The following criteria will be used as guidelines during the selection: (1) accessibility of the farm, (2) availability of enough land with uniform soil, and (3) farmers' willingness to cooperate in the trials.

The trials will be carried out on each of the selected farms and at the university farm, Kabanyolo. The existing cropping pattern will be examined using the farmers' management techniques and improved management practices, e.g., size of the holes for planting bananas, weeding frequency, mulching practices, use of improved varieties and fertilizers, and improved crop protection procedures. The overall purpose of the trials is likely to be: (1) determine the optimum yield per unit area of the bananas and the component crops and to measure the impact of different agronomic practices on the output; (2) determine the economic levels of crop protection procedures;

(3) examine the fertilizer needs of the banana; and (4) monitor the economics of the cropping patterns, e.g., labour required for planting and weeding.

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IMPROVEMENT AND DEVELOPMENT OF PRODUCTION PRACTICES AND PREPARATION AND PRESERVATION METHODS OF INDIGENOUS VEGETABLES IN MALAWI

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In the quest for food and the struggle for human survival, indigenous vegetables and fruits have historically played an important role in developing countries. Daily consumption of these vegetables and fruits has provided the bulk of vitamins, essential minerals, protein, and some carbohydrates needed for normal human body growth and development. Unfortunately for decades, it has been accepted that the indigenous vegetables and fruits are poor-man's crops and their high nutritional value has been virtually ignored and they are not included as important crops in agricultural statistics in many developing countries, including Malawi.

In Malawi, where over 90% of the population lives in rural areas (Anonymous 1977), indigenous vegetables (Table 1) form the main relish taken with "nsima" (cooked maize flour) and provide most of the vitamins, essential minerals, and some protein in the diet of the people (Thomo 1983, unpublished data; Butao 1981; Pereira and Bergum 1976; Platt 1940). The nutritional value of indigenous vegetables is comparable to and in most cases surpasses that of most exotic vegetables (Okigbo 1981; Butao 1981; Grubben 1977; Schmidt 1971), but their economic potential has not been explored and, hence, is regarded as inferior to that of exotic vegetables (Grubben 1977; Epenhuijsen 1974). Limited survey reports show that a large number of different species of indigenous vegetables are consumed by the rural population (Thomo 1983, unpublished data; Williamson 1956; Platt 1940).

In spite of the dietary importance and economic potential, no recommended production practice packages are available. Most of the indigenous vegetables grow unattended either in farmers' fields, in association with other crops, or on resting land or forest. For some, they could be found growing as volunteer crops around farmers' compounds, with minimum or no care at all (Thomo 1983, unpublished data). As a result of the nature of their production, fresh indigenous vegetables are available mainly during the wet season, with very few fresh vegetables being available during the dry season, except for those preserved in the dry form. The situation is worse when it is realized that even researchers, extension workers, and nutritionists have virtually ignored these vegetables. Little research has been done to improve their yield and quality, or even to collect and document the available species and cultivars of indigenous

Table 1. Some common indigenous vegetables consumed in Malawi.

Amaranthus sp.
Adenia gummifera
Gynandropsis gynandra
Crotalaria anthyllopsis
Bidens pilosa
Cocciria adoensis
Cerabotheca sesamoides
Cleome monophylla
Hibiscus acetasella
Hibiscus sabdariffa

vegetables found throughout the country, not to mention documentation of their agronomic characteristics, cultivation methods, nutritional value, and methods of preparation and preservation for use during the period of scarcity, which lasts for about 7 months.

In recent years, the need to improve the yield and quality of indigenous vegetables has become apparent. Most of the indigenous vegetables are on the verge of extinction as a result of deforestation, intensive cultivation of other crops, massive land clearing, and construction of roads, houses, and urban centres. Due to the unavailability of indigenous vegetables and coupled with rising costs of meat, fish, milk, eggs, and production inputs for exotic vegetables, the majority of the people cannot meet their daily dietary requirements. Hence, any coordinated research effort aimed at improving the yield and quality of indigenous vegetables will go a long way toward helping the majority of the people meet their dietary requirements. This undertaking would contribute significantly to the government's efforts to combat the problem of malnutrition, thereby improving the health of the people and enhancing their ability to work, which contribute to the economic development of the country.

In light of the problems associated with the production and use of indigenous vegetables, it is proposed that a multidisciplinary research project be carried out at Bunda College of Agriculture to improve and develop production practices and preparation and preservation methods of the woefully neglected indigenous vegetable species in the country. The research team will be comprised of a horticulturist, farming systems agronomist, human nutritionist, and an extension specialist/rural sociologist. The project will initially be confined to Lilongwe Agricultural Development Division (Central Region) and when fully developed will cover other major ecological zones throughout the country.

PROJECT OBJECTIVES

In general, the project's objectives are to: (1) collect and catalogue indigenous vegetable germ plasm; (2) document the agronomic characteristics and nutritional value of indigenous vegetables; (3) select suitable species and cultivars that can be grown in the different ecological zones of the country; (4) document various uses of indigenous vegetables in different parts of the country; (5) document cultural/sociological and economical barriers associated with the production and consumption of indigenous vegetables; and (6) promote the marketing of indigenous vegetables.

The specific objectives of the project are to: (1) document types of indigenous vegetables; their methods of production, preparation, and preservation; and their nutritional value; (2) improve the yield and quality of indigenous vegetables; (3) improve the nutrition of the people; and (4) improve the economic value of indigenous vegetables.

METHODOLOGY

To accomplish all of these objectives, the research project will be carried out in six phases over a 5-year period. Project activities will be coordinated from Bunda College of Agriculture.

Phase One

This phase will involve detailed documentation of all types of indigenous vegetables that are widely consumed in each of the ecological zones of Malawi and the collection of seed of the indigenous vegetable species. To accomplish this, several detailed surveys will be conducted in each of the ecological zones during the wet and dry seasons of the year. During the survey, information will be gathered on growth habit, habitat, time of year available, cultivation practices, uses, portion consumed, preparation and preservation methods, and cultural/sociological and economical barriers. Seed collection will also be carried out during the survey.

This phase will require inputs from all members of the research team to formulate questionnaires pertinent to their respective areas of expertise. Enumerators will also be employed to work with the researchers in conducting the survey in each ecological zone. An accession notebook will be maintained for this purpose.

Phase Two

Phase two will involve seed multiplication and preliminary field and laboratory trials to screen for quality (nutritional value, taste, texture, appearance, and size), yield, and desirable agronomic characteristics. Field trials will be conducted in many ecological zones and yield potential and agronomic characteristics of each indigenous vegetable species will be assessed. Laboratory tests for quality will be carried out at Bunda College. Samples of the edible portions of each indigenous vegetable species will be assessed for quality. Participation of farmers' families from different ethnic groups and areas will be sought during the assessment of taste, appearance, and texture of the edible portion mostly using organoleptic tests.

Preliminary field trials will require inputs from the horticulturist and farming systems agronomist, whereas the assessment of quality will require the human nutritionist to work hand-in-hand with the horticulturist.

At the end of this phase, it is hoped that the results from the assessment of agronomic characteristics and yield in different ecological zones and the quality of each indigenous vegetable species will form the basis for the selection of those species and cultivars that will be used in phase three.

Phase Three

This phase will involve extensive field trials and quality (nutritional value, taste, texture, and appearance) assessment under various methods of preparation and preservation. Field trials will focus on production practices, such as plant density, time of planting, organic manures (green manure, compost, farmyard manure), fertilizers and water requirements, and pest control, and cropping systems (mixed cropping, monocropping, rotation) in each ecological zone. Quality assessment will focus on the influence of different methods of preparation for eating and preservation for future consumption on the retention of vitamins, essential minerals, and protein, and effects on taste, texture, and appearance.

Field trials will be conducted in all ecological zones at agricultural research stations wherever possible. Assistance will be sought from the research stations to provide land and accommodate project technical assistants who will be looking after the trials. The farming systems agronomist and the horticulturist will be responsible for planning and designing all field experiments and the collection and analysis of data. Whenever necessary, collaboration with the entomologist, pathologist, and nematologist will be sought. Quality assessments will be conducted at Bunda College and when the participation of farmers' families (from different ethnic groups and areas) is required, particularly regarding taste, texture, and appearance, assistance will be sought to conduct such tests in several training centres throughout the country. The human nutritionist will collaborate with the horticulturist in assessing the quality of indigenous vegetables under different methods of preparation and preservation.

During this phase, in both the field trials and the study of preparation and preservation methods, consideration will be given to the question of whether or not farmers' families can afford the cost of production, preparation, and preservation of the indigenous vegetables in cases where inputs or other ingredients are used. At the end of this phase, it is hoped that information on appropriate production practices (for each of the selected indigenous vegetable species from phase two) in different ecological zones and the effects of preparation and preservation methods on quality will be gathered. Based on this information, simple and cheap production practices and cropping systems that optimize yield and quality of each indigenous vegetable species or cultivar and land use will be considered appropriate for testing with farm families. Similarly, preparation and preservation methods that best retain high quality and palatability of the consumed vegetable and, at the same time, are relatively easy and cheap will be considered appropriate for experimental introduction to farm families.

Phase Four

This phase will involve on-farm trials and demonstrations of the selected production practices and preparation and preservation methods from phase three. A randomly selected number of farm families in several areas (ecological zones) will be asked to grow the selected indigenous vegetable species or cultivars following the production practices developed in phase three. The yield and quality of each indigenous vegetable species or cultivar obtained by farmers will be compared with research station results and, where necessary, modifications on production practices will be made. During the growing season, surrounding farmers and extension workers will be invited to field days at both the farmers' and stations' fields. Similarly, farmers' wives will be shown potentially better methods of preparation and preservation of each indigenous vegetable species developed in phase three. The farmers' wives will be allowed to prepare and preserve the vegetables as advised and several samples of prepared and preserved vegetables will be collected over a period of time for quality (nutritional value, taste, texture, and appearance) evaluation. The results will be compared with those obtained at the main stations (Bunda College and training centres) and, where necessary, modifications in preparation and preservation methods will be made to take into account the constraints affecting farm families. In addition to these on-farm trials and demonstrations, local workshops will be conducted for extension/homecraft workers and randomly selected farm families in various training centres where the participants will be trained in production and preparation and preservation methods for each indigenous vegetable species.

In this phase, more inputs will come from the extension specialist/rural sociologist who will collaborate with other researchers in their area of expertise. This phase will require a more co-ordinated effort on the part of the project team members and the measure of success of the project will depend on how successfully this phase is carried out.

Phase Five

Phase five will involve efforts to improve the economic status of the indigenous vegetables and evaluate the success or failure of the research project. Initially, samples of indigenous vegetables will be on display at various markets (rural and urban), with posters and individuals explaining the nutritional value, cooking quality, taste, recipes and preservation methods, and comparisons of these attributes with those of exotic vegetables. Simultaneously, marketing trends will be followed for a period of time through a survey. In the survey, information on the number of customers buying indigenous vegetables, number of producers taking indigenous vegetables to the market, price changes, customer and producer attitudes, and preferences for different types of indigenous vegetables compared with exotic vegetables will be gathered through interviews and questionnaires.

In this phase, inputs from the extension specialist/rural sociologist, in collaboration with the horticulturist and human nutritionist, will be required and, wherever necessary, assistance from an agricultural economist will be sought. Analysis of the data that will be gathered from this phase will indicate whether or not the economic status of the indigenous vegetables has significantly changed for the better.

Phase Six

This phase will involve compilation and documentation of all the data gathered from phases one through five. The data will be summarized and recommendations will be made. Bulletins on production practices and preparation and preservation methods of the superior indigenous vegetable species will be prepared for extension/homecraft workers and the use of farm families.

SUMMARY

The research project to be developed at Bunda College of Agriculture is intended to achieve improved yield, quality, and economic value of the virtually unknown indigenous vegetables through the improvement and development of better production practices and preparation and preservation methods and the people's awareness of the importance of the indigenous vegetables. Such an achievement would contribute to the improvement of the nutritional status of the people and the economic development of the country. To accomplish the objectives of the project will require a coordinated interdisciplinary research (variety collection and selection, cropping systems, nutrition, and marketing) approach. The involvement of farm families in some of the phases of the project is certainly innovative and will ensure that the final recommendations reflect the need and constraints of the people the project intends to assist.

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ORGANIZATION OF CROP IMPROVEMENT

ORGANIZATION OF TEAM RESEARCH FOR CROP IMPROVEMENT IN ETHIOPIA

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Of a total area of 122 million ha, about 85 million ha (70%) is considered to be suitable for agricultural production in Ethiopia, although only 9 million ha (10%) is currently cultivated. However, agriculture is the mainstay of the economy, providing a livelihood for about 85% of the population, estimated at 32 million people, and contributing to over 50% of the gross domestic product (GDP) and 85% of export earnings.

That Ethiopia offers an unusually wide range of ecological conditions, due to variable altitude and rainfall conditions, has given rise to the cultivation of sundry crops, some of which are of Ethiopian origin. On the whole, cereals occupy about 53%, pulses 13%, and oil crops 4% of the total cultivated land.

Most of the cropland lies in the highlands or river valleys. Cultivation in the mountain zone, including all land over 4000 m above sea level, is largely precluded by cold weather. Grains such as wheat, tef, and barley grow in the cool highland zone, extending from 2500-4000 m.

These crops, as well as corn, sorghum, and millet, do well in the temperate highland zone, which extends from 2000-2500 m. Coffee and ensete (false banana) do well at this altitude in the southwest, where the average rainfall is higher. Cultivation below 2000 m, i.e., in the hot zone of the semidesert, is possible in river valleys or with irrigation and consists of tropical and semitropical produce.

In spite of the inestimable role that agriculture plays in the country's national economy, its productivity has been very low. The national average yield of major cereals has never reached the attainable potential of the crops.

The high productive potential, which paradoxically is tied up with the low productivity of agriculture, can be attributed to many interrelated production constraints and factors. Some of these constraints are institutional, others pertain to natural and environmental factors, while still others relate to the lack of improved technologies prevailing at different times in the country.

Therefore, these technological, natural, and institutional barriers have to be somehow alleviated so that better agricultural development strategies can be made. The need for and development of an effective research component to cater to the various agroecological zones, the search for and establishment of appropriate research lines, and the coordination of these efforts will go a long way toward solving part of the problem.

RESEARCH APPROACH

To accelerate agricultural productivity and promote economic growth for countries heavily dependent upon agriculture, the first and foremost attempt should be directed toward carrying out agricultural research. Even though this may be the case, sustainable results can only be achieved if the preferred research operates in a systematic manner.

The Institute of Agricultural Research (IAR), although presently consisting of 5 departments and 15 interdisciplinary teams working in 7 main stations and 22 substations, has gone through many complex and practical experiences in attempting to build an efficient and sound research effort.

Prior to the strengthening of IAR, some rudimentary research was accomplished by different colleges and institutions. In cognizance of the difficulties encountered in research coordination, IAR has tried to synchronize its efforts and coordinate its station-based research.

Until 1976, research programs were prepared and implemented on a station/location basis, where sections in each discipline were serving only the programs and priorities of the particular station.

This approach was found to be weak in terms of focusing research on the pressing needs of the farmers or on agricultural development in particular. It tended to produce academically oriented research activities and failed to organize the scattered research work outside IAR, which resulted in duplication of effort. The need to coordinate research across stations has since become the immediate alternative, which led to a restructuring of the technical work on a departmental basis during the 1976/1977 crop year. At this time, eight research departments were created.

Although this new approach allowed for better coordination of research activities across stations, through departmental coordinators, it was again found to constrain further development and coordination.

Thus, in 1979, the departmental structure was reformulated to consist of 15 national commodity/crop oriented multidisciplinary research teams, namely: fruits and nuts, roots and tubers, vegetables, spices, wheat, barley, tef, maize, sorghum, lowland oil crops, fibre crops, lowland pulses, highland oil crops, highland pulses, and coffee. Each team is composed of a breeder, an agronomist, crop protection specialists (weed, entomology, pathology), a soil-fertility specialist, and others as required/available. Team members may be drawn not only from IAR but also from Addis Ababa University, according to the availability of relevant expertise. Today, each team is concerned with the improvement of a particular crop and is working under its respective team leader. The team leaders, in turn, are coordinated by the team leaders' coordinator. In addition, five departments (animal science, pasture, and forage crops; crop protection; soil science; agricultural engineering, home science, and food technology; and socioeconomics), which consist of four, four, two, three, and two sections, respectively, exist in the institute.

Although it is for the crop improvement program that the multidisciplinary research approach was made operational, surveys and studies are in progress to develop the same system for animal resource improvement research, which is now scattered and less coordinated.

In general, the multidisciplinary team approach paved the way for the formulation of an all-inclusive research program. Initially, IAR was facing problems of developing appropriate research programs but now the definition of agricultural research programs, which reflects their needs, is helping to achieve better results due to the active participation of user organizations. This is expressed during the various stages of program development.

In short, the proposed stages of program development or levels of screening, which are viewed in terms of the prevailing stage and researchers' time, are as follows:

(1) National Crop Improvement Conference (NCIC): This is a meeting that involves more than 300 people and is designed to evaluate the performance of previously recommended research results, recommend the release of improved crop varieties and proven cultural practices, and indicate future lines of investigation. NCIC is believed to play an important role in that the users of agricultural research findings are given the opportunity to express their concerns and problems to those persons conducting the research and involved in directing and planning the national agricultural research effort.

(2) Pre-Preview: This is a recently introduced stage at which members and/or researchers meet on a team basis to discuss and check on the practical problems likely to arise in executing proposals and research methodology and scientific interest.

(3) Preview: This stage involves meetings at which acknowledgment of and discussions on the merits of research lines are given attention and where screening of research proposals in light of needs, objectives, and resources for research rather than factors of scientific interest and research methodology take place. It is also the phase during which user organizations are best represented to express their interests.

(4) Review: At this stage, a meeting is held at which programs are rated against some selected priorities. Here also, previously approved projects are discussed. Participants at this meeting include officers in charge, department coordinators, team leaders, invited scientists, and IAR management. After review, the approved research programs are compiled and passed on to higher authorities for financing.

CONCLUSION

The formation of multidisciplinary crop commodity teams in IAR has proven its vitality through the realization of an integrated research program that permits the participation of all other agriculturally involved institutions in an attempt to find solutions to the great variety of agricultural problems existing in the country. Moreover, the research program has benefited greatly from the approach because it is streamlined to focus on priority crops/crop groups, with a joint effort for their improvement.

LINKAGES BETWEEN RESEARCH AND EXTENSION IN ETHIOPIA

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Ethiopia, with an area of 122 million ha, is predominantly an agricultural economy in which more than 86% of the population is engaged in agriculture. The present agricultural practices of Ethiopian farmers are traditional in nature and the overall production per hectare is low. This low productivity could be improved through extension by introducing modern agricultural technologies that have been developed by research institutes.

In 1974, the Institute of Agricultural Research (IAR)/Extension Project and Implementation Department (EPID) (now the Agricultural Development Department (ADD)) established a joint research and extension program to cover different parts of the country. This program continued until 1976/1977.

A strong resolution was passed by the participants attending the National Crop Improvement Conference (NCIC) meetings held between 1978 and 1980 that IAR and ADD should form a strong link so that the research results of the conference could reach most peasant farmers. In 1980/1981, a joint agreement was reached between IAR and ADD to run adaptive tests in potential areas of crop production. Accordingly, the IAR/ADD joint research and extension program was reactivated with the following objectives: (1) to revive the already discontinued IAR/EPID research program but with better coordination and a better approach, (2) to involve researchers as well as experts in extension work so that constant interaction and dialogue can be maintained, (3) to reach out to more representative locations that are already covered by extension services but receive limited agroecological coverage from IAR, (4) to improve the existing weak and ineffective link between research and extension through a coordinated effort, and (5) to formulate a suitable extension package and provide research innovations to farmers through field demonstrations.

In setting out their strategies to implement the program IAR and ADD have elaborated further on their responsibilities. The program is run by a committee made up of representatives from both IAR and ADD. The committee meets once or twice a year to hear annual reports and make recommendations for the coming season.

ORGANIZATIONAL RESPONSIBILITIES

The responsibilities of IAR are to assign one coordinator to ADD; participate fully in the planning, designing, and evaluation of trials; prepare and supply planting materials and trial guidelines; participate in site visits and supervision; participate in the training of field staff; and submit recommendations based on research findings.

The responsibilities of ADD are to provide facilities, such as offices, materials, and transport, at the field level; ensure that regional staff pay proper attention to the program and any follow-up activities; participate in planning, program establishment, and assessment of trial sites; make trial results available on time to researchers; advance recommendations based on trial results to the appropriate areas; and assign one coordinator to the head office and junior experts to work on-site.

COORDINATION OF THE PROGRAM

The program is run by a committee from IAR and ADD. The committee has a chairman and two coordinators, one from each of the two organizations.

It is the responsibility of the chairman to give advice to the coordinators, call general meetings as needed, and transmit those resolutions made by the committee that can't be solved by the coordinators to IAR and ADD.

It is the responsibility of the coordinators to participate in site selection; collect seeds, fertilizers, and guidelines from researchers and dispatch them to the appropriate sites; purchase materials; follow up land preparation, planting, and cultural practices by collecting data at the sites; collect row data and seeds from the sites and dispatch these to the researchers for analysis, quality tests, and recommendations; collect analysis and recommendation reports from the researchers and compile a progress report each year; and arrange training for field staff.

SITE SELECTION

Each site consists of an area of fenced farmland with a minimum of facilities. The criteria used for selecting sites included the production potential of the area, whether or not the site is representative of the area, and whether or not there was an IAR station or substation in the area (emphasis being given to extending IAR's national coverage). Before beginning any activity in the area, the background of each site was studied.

TYPES OF TRIALS CONDUCTED AT IAR/ADD SITES

Trials were conducted to study adaptation of cereals, pulses, oil crops, and horticultural crops; sowing dates; seeding rates; pests, diseases, and weeds; types and rates of use of fertilizers; and drainage and lime content of the soil.

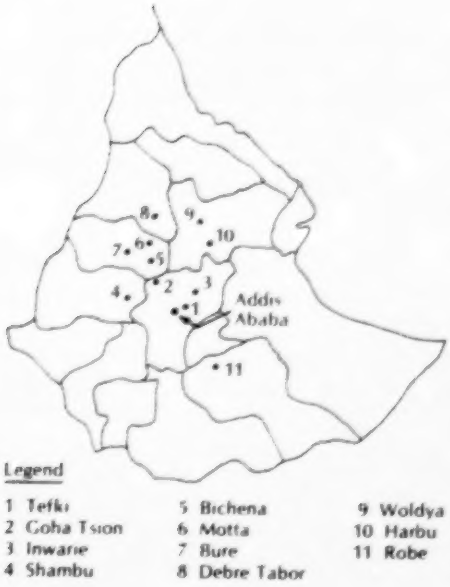

Fig.1. IAR/ADD joint research and extension program trial sites.

In 1981/1982, the IAR/ADD joint research and extension program began trials at 11 sites in six administrative regions (Fig.1), each site covering an area of 1 ha. During the 1983/1984 season, trials were carried out on 18 crops and observations on lime application were also made (Table 1). All trials showed good performance and similar yields to those obtained at IAR stations. The trials were evaluated by researchers from IAR, the coordinators, and experts from ADD. After harvest, the coordinators sent all of the data from each site to researchers for analysis and recommendations. Later, after analysis and recommendations, a report was sent back to the coordinators for the preparation of a progress report.

TRIAL MODIFICATIONS

During the 1981/1982 season, most of the trials at the IAR/ADD sites were national variety yield trials, prenational yield trials, observation trials, and variety trials. However, plot sizes and the number of trial replications were not uniform. The technical committee has since suggested that the number of replications be set at four and, where fertilizer is applied as a second factor on a variety trial, it will only be applied to two of the four replications; the length of the plot be limited to 5 m; the number of varieties to be tested be limited to 10 or less; and the varieties to be tested at IAR/ADD sites be either released or those being considered for release within 1 or 2 years.

Table 1. IAR/ADD research program, 1983/1984.

Crop	Goha Tsion	Bichena	Motta	Bure	Debre Tabar	Woldya	Harbu	Inwarie	Tefki	Robe	Shamb
Cereal											
Bread wheat	X	X[a]	X	X	X	X		X[a]	X	X	X
Durum wheat	X	X	X	X		X		X	X	X	X
Barley	X		X	X	X					X	X
Tef	X	X	X	X	X	X	X		X	X	X
Late-set sorghum						X					
Early-set sorghum							X				
Maize			X			X	X				
Pulses											
Haricot bean						X	X				
Cowpea						X	X				
Lentils	X	X	X		X	X		X[a]	X[a]	X	X
Faba bean	X	X	X		X			X		X	X
Field peas	X	X	X		X			X		X	X
Soybean				X		X	X				
Oil crops											
Linseed	X		X	X	X			X	X	X	X
Noug[b]	X	X		X	X	X			X		X
Sesame								X			
Sunflower			X	X		X	X		X	X	
Rapeseed			X	X	X					X	X
Mustard			X	X	X					X	X
Potato			X	X	X					X	X
Lime application	X		X	X	X						X

[a] There will be additional sowings.
[b] Noug = Gezoita abyssinica (Niger seed).

FUTURE PROGRAMS

The IAR/ADD joint research and extension programs will be expanded through time as more experience is gained. Any variety that produces a good yield for two seasons will be planted for the third season in a larger plot or on farmers' fields to study its progress and after that it will be released to the farmers.

SUMMARY OF DISCUSSIONS

ORGANIZATION OF CROP IMPROVEMENT PROGRAMS

In most eastern and southern African countries, agricultural research is presently conducted with little coordination among the various bodies involved. Research entities often include ministries of agriculture, crop parastatal bodies, autonomous agricultural research institutes, and universities. In many cases, research is conducted without identifying the basic problems farmers face and recommendations may not reach them. This may lead to duplication of research efforts and uneconomic utilization of research funds and scarce resources.

In order that limited resources be utilized efficiently, there should be a national research-coordinating body responsible for coordinating, monitoring, and evaluating agricultural research. This cropping improvement coordinating committee (CICC) should meet regularly to study the applicability of research being conducted and should be vested with the power of approval of initiation and continuation of research programs. It should also assist in the creation and coordination of crop commodity teams (CCTs) across institutions. In addition to a technical advisory role, the CICC would be responsible for ensuring that available funds are allocated in accordance with established research priorities.

The current orientation, along commodity lines, of agricultural research in Africa is still viable and applicable. However, CCTs should be organized nationally and encompass all research institutions in the country having the personnel available to make a relevant contribution. CCTs may be formed for one or a group of related crops. Each CCT, under the leadership of a national coordinating scientist, should include members with relevant expertise, e.g., plant breeder, agronomist, plant pathologist, etc. Certain members of a particular team might only participate on a part-time basis, e.g., food scientist, and may serve concurrently as members of several commodity teams.

Commodity teams should cooperate closely with farming systems research teams which will have as one of their responsibilities identifying research priorities for a given farming area. Ideally, a farming systems team, in addition to a general agronomist and a socioeconomist, will include scientists drawn from relevant CCTs. This arrangement will facilitate the necessary on-station and on-farm aspects of the research programs of both kinds of teams. Although CCT staff may be part-time members, they should be involved in the planning and implementation of the entire program.

In many African countries, opportunities are missed by not involving universities in research to their full potential. It is in the universities that there is a concentration of trained personnel, yet only a few scientists are involved in agricultural research, while others are left out or feel that research is not their responsibility. This leads to underutilization of human resources. Universities, therefore, should undertake specific tasks in agricultural research and become actively involved in all of its aspects.

The main stumbling block between the researcher and the extension service is the lack of an effective communication system. With the director of extension on the CICC, effective communication should be readily established. Furthermore, local extension workers should always cooperate with and advise the farming systems research teams and CCTs in identifying problems and establishing priorities.

SETTING THE TECHNICAL OBJECTIVES OF A CCT

CCT objectives should be formulated in cooperation with farming systems research teams and the CICC. Researcher/farmer contact should be facilitated by local extension workers. Ranking of research objectives can be accomplished based upon the relative importance and size of the target group within the region or country. Adequate consideration must be given to the farmers' ability to implement the proposed technology or variety and be based on its adaptability to agroecological limitations. Also, objectives must take into account national, financial, infrastructure, and personnel resources.

Sources of Information

Initial sources should include existing data on production, consumption, marketing, demographic trends, and climate and literature searches. In the absence of adequate data, a survey is an important tool in both CCT and farming systems research programs and should be used by them when necessary. The type of survey required will depend upon the nature of the problem, e.g., a formal questionnaire-type survey can provide a quantitative assessment of the conditions of a region, whereas informal discussions with farmers may be particularly useful for providing insights into their understanding of their needs, as pointed out in the papers by Kwapata and Edje and Onim.

Development of New Germ Plasm and Agronomic Practices

It is recognized that if a new agricultural recommendation is to be accepted widely, it needs to be feasibly designed for incorporation into the prevailing production system. It may be necessary, therefore, to develop one or more varieties and practices that are suited to different agroecological and socioeconomic conditions.

Exchange of ideas on an international/regional level can be accomplished through regional workshops and seminars. Cooperation with international research organizations is necessary but should be carefully focused upon technical issues determined by the CCTs; such cooperation should be mutually beneficial and involve a two-way flow of ideas and experience.

MULTILOCATION AND ON-FARM TESTING

Both multilocation testing (MLT) and on-farm testing (OFT) are important components of an effective crop-improvement program. The need to develop appropriate varieties and agronomic practices for farmers implies a research effort that tests not only the range of adaptability (MLT) but also the suitability of crop improvements to farmers, particularly small-scale farmers (OFT). These activities, therefore, are considered to be an integral part of the research process of a crop-improvement program and should be addressed by CCTs.

Multilocation testing has traditionally been considered to be the final step in the process of selecting technology and technological components. Although on-farm testing can be viewed as a subsequent step, limited on-farm testing can usually be incorporated into the earlier stages of crop-improvement programs.

Functions of Multilocation and On-Farm Testing

The major function of multilocation testing is to assess the adaptability of selected crop varieties across a number of agroecological zones, generally on a national basis. MLT provides an indication of the performance of the technology in areas for which it may not have been initially developed. A minor function of MLT is to provide a demonstration for the farming community, who may visit the sites to assess the growth and yield of each variety.

On-farm testing has four functions: (1) to assess the adaptability of a potential recommendation to environmental variation within a major agroecological zone; this may take into account the influence of farmer management; (2) to test the "fit" of the recommendation within the farming system; (3) to determine farmers' perceptions of the recommendation; and (4) to demonstrate recommendations to the farming community.

Multilocation Testing

Multilocation testing of varieties or practices is being conducted by most crop-improvement programs at established research stations and substations. Esele reported that the Uganda sorghum program has the use of 40 Variety Trial Centres. In some instances, farmers' fields or cooperating institutions can be used to provide other sites, and further cooperation with other institutions would often be useful to extend the range of environments covered. Many programs, however, have limited resources, especially transport facilities, available for this purpose.

MLT is usually managed by the research institution under an optimum set of management practices that tend to emphasize the yield potential of a new technology. Because the generally high fertility of soils on research stations could bias the responses of the treatments being tested, it is important that the crop-management levels of these tests closely reflect the generally lower levels likely to be used by small-scale farmers adopting the new technology. The results of the MLT would then be more representative of what farmers can be expected to obtain.

For some programs, this strategy would imply a major reorganization of objectives, focusing on variety development for low and moderate input levels.

On-Farm Testing

Types of On-Farm Testing

"Farmer-managed" on-farm testing is that in which the farmers execute the production processes under their own management, implementing the advice and recommendations of the researcher as they see fit. One, or at most two, experimental factors are sufficient to measure the suitability of the practices under the farmer's management conditions, and this simplicity assists the farmer in understanding and contributing to the experiment. In "researcher-managed" testing, on the other hand, the scientist manages the production processes but uses a field borrowed or rented from the farmer. "Jointly managed" testing represents an intermediate situation in which the researcher requires certain experimental conditions to be followed, while other production processes are the responsibility of the farmer.

Each type of on-farm testing has specific functions. Researcher-managed testing examines the effects of variability of the physical factors of the farms, e.g., soil fertility and drainage. Jointly managed testing assesses the variability in performance of the treatments due to differences among farmers in their management of non-experimental factors. Farmer-managed testing permits assessment of the feasibility of an innovation and its adaptability when all production factors are managed by the farmer. As the degree of farmer management increases, traditional research "control" is reduced and variability of results is increased. As programs gain experience with the different types of on-farm testing, their distinctions between the function of the testing and how it is carried out should become better defined.

Site Selection

A clear definition of the target area is the first step in site selection. Usually, this will be a region that is environmentally uniform or falls within a predetermined range of altitude, rainfall, or temperature. Within this region, the research site is selected because it is environmentally typical or falls within the desired range of variation. It is important that the crop under investigation be either a significant part of the cropping system at the testing site or one that is seen by the farmers as being a desirable addition.

It is essential that local government or party officials approve of the proposed on-farm work and be consulted at the outset of site selection. The willingness of other projects in an area to cooperate may be an important factor in determining the appropriateness of a particular site. The accessibility of the site must also be considered carefully, bearing in mind that farmer-managed testing may require less frequent attention from researchers and may be located in a more remote area than a researcher-managed test.

Farmer Selection and Participation

One of the most difficult aspects of developing on-farm testing is making contact and establishing cooperation with farmers. When representative farmer management is required, as defined by the objectives of the test, a program in eastern and southern Africa will usually want to work with "typical" farmers, often those farming near the subsistence level. For such farmers, trust in the researcher and the element of farmer risk are very important.

Zeigler and Manassé indicate that a program can gain farmer trust very rapidly by working initially with farmers who are acquainted with a member of the research staff. A known and trusted individual on the research team may help allay fears that land provided for on-farm research will revert permanently to the government. Cooperation from the outset with local extension agents may also help to develop trust. The senior researcher should be present, either for initial farmer contact or at a critical phase of the experiment (e.g., planting), to demonstrate to the farmers that their participation is being taken seriously. The farmers selected for the program should normally be full-time farmers who depend upon farming for their livelihood. Ideally, contact should be made with the family member or members who do most of the actual fieldwork and make the day-to-day decisions. The farmer, of course, must be interested in participating in the particular type of test being planned, as coercion of the participant is unlikely to produce reliable results. Adequate explanation of the researcher's objectives is necessary and can sometimes begin at a village meeting, a technique used by Maingu in Tanzania.

A farmer's aversion to risk is a very important consideration throughout much of Africa. Farmers, therefore, need to be assured that they will be no worse off for having participated in a test. Because almost all tests employ the farmer's methods and varieties as a control, their return may serve as a baseline level of production. For experimental plots that fail to attain this level of production, compensation for the farmer, either in cash or in kind, would be necessary. In researcher-managed testing, risks may be avoided by renting the field or by purchasing the harvest. In farmer-managed testing to evaluate varieties, intercropping with other typical crop species (where applicable) may substantially reduce risks to the farmer.

Where active participation by the farmer is desired, special efforts must be taken to ensure that the farmer understands and agrees with the objectives of the test and feels like a partner in the research. Onim points out that placing full responsibility for the tests with the farmer should lead to quicker adoption of a successful new variety because the farmer would become convinced of the merits of the variety as the test progressed.

Field and Plot Characteristics

Although fields selected for testing must be reasonably uniform, the researcher should avoid selecting only the best fields. Consequently, fields should be selected well in advance of the growing season and when a crop is present. To minimize inconvenience to the farmer, the size of the field chosen and the plot size used depends not only on crop characteristics but also on land availability on the farm. Because the inherent variability in farmers' fields is often high, plot sizes should be larger for on-farm testing than for tests conducted at experimental stations--two or three times larger. Large plots also make it easier for farmers to understand the experiment and comment on the feasibility of a treatment that involves a change in working pattern (e.g., plant spacing or weeding). Each treatment only needs to be conducted once in a given farmer's field, with comparisons being made among farms.

Treatment Design and Management

Even though the researcher is responsible for the manner in which experimental treatments are applied, the experiment should be kept simple, preferably involving a single variable. If other factors are introduced, it may be preferable to introduce them sequentially so that the participating farmer can still follow the experiment, e.g., large plots may be split to enable the testing of a second factor, such as the time of weeding, during the course of the season. Because farmer-managed experiments depend upon the farmer's ability to follow the experiment, only one (two at most) factor should be studied at any time.

Management of Nonexperimental Variables

In researcher-managed testing, specific instructions for all management practices, e.g., from land preparation to sowing date, need to be given to the research staff or farmer. When there is joint participation, guidelines and suggestions may be appropriate. Discussions among farmers and researchers at the planning stage or in advance of a particular operation may lead to more appropriate decisions being made on particular management practices and their timing, e.g., Onim reported that the farmers' traditional spacing for pigeon peas was more appropriate for evaluating new varieties under dry-land conditions than the researchers' recommendation for close spacing. In farmer-managed testing, all operations are conducted by the farmers, following their traditional methods and timing, which they are free to vary. The researcher must always take great care to avoid inadvertently introducing a nonexperimental variable that may bias the performance of treatments, e.g., a comparison between improved maize varieties and a local variety provided by the farmer can be biased by relatively poor germination of improperly stored local seed. A valid comparison between the genetic potential of introduced and local varieties, on the other hand, could be attained by requesting seedfrom the farmer the year before the experiment is to be conducted and treating it exactly as the experimental seeds are treated.

Evaluation and Interpretation

In addition to assessing yield differences, the researcher will want to obtain the farmers' impressions of the progress of the experiment throughout the season. If a particular agronomic practice or variety is to be judged successful under specific conditions, the farmers must recognize it as being superior to their own. This is unlikely unless the improvement in yield is of the order of 30% or more. Thus, a difference of 10%, even if statistically significant, will be of little interest to the farmer. Criteria other than yield will also be important at this stage, particularly quality considerations and compatibility of the treatments with the farmer's cropping system. Perhaps the most important reason for conducting on-farm testing is to identify previously unsuspected factors that may reduce the acceptability to farmers of a particular kind of innovation.

On-farm research is at least as demanding scientifically as conventional research conducted at experimental stations and considerably more demanding in terms of planning, logistics, and farmer contact. The time devoted by the researcher to consultations with farmers and advanced planning in conjunction with them can be very fruitful, in terms of orienting research priorities toward farmers' needs even before the first on-farm experiment begins, and ultimately leading to the application of the research results by the farmer.

POLICY ISSUES AFFECTING CROP IMPROVEMENT

This publication is concerned primarily with methods by which researchers can enhance the effectiveness of research programs aimed at helping small-scale farmers. Several other factors, however, influence this and contribute toward determining the efficiency with which research resources are utilized. These factors are not controlled by researchers, but require consideration by policymakers at the national level. The principal issues are:

(1) Coordination of research at the national level: A national coordinating committee for crop research is needed to bring together the leaders of crop-research and farming-systems teams for the purpose of coordination. Crop-research teams should be interdisciplinary in nature and directed toward the improvement of specific commodities. Their functions should include planning and evaluating research, and coordinating related programs of all institutions conducting research within that country.

(2) Linkages between research, extension, and farmers: Effective research leading to the adoption of productive technical innovations by farmers requires good two-way communication between researchers and extension personnel and between each of these groups and the farmers themselves. Senior extension personnel should be included as members of the coordinating committee for crop research. Farming-systems teams should be the main link between crop-research teams, extension personnel, and farmers, but crop-improvement researchers also need an opportunity to interact directly with field extension workers and farmers.

(3) On-farm research for crop improvement: The importance of on-farm research as part of crop improvement programs must be recognized. Some research must be conducted in farmers' fields to improve the definition of the specific objectives of programs and to test promising technologies under representative conditions and employing criteria of evaluation that are important to farmers. The extent to which crop improvement programs engage in on-farm research may be reduced, but not eliminated, where farming systems research programs are active.

(4) Resource allocation: Significant improvements in crop productivity, through development of technology, can be expected only if research receives adequate support, both financial and in terms of scientific manpower and training. Strong national support is essential to ensure adequate levels of staffing, develop the full potential of research staff through appropriate training, and finance effective field programs that include adequate provisions for on-farm testing.

(5) Procedures for assessing research results: Nationally recognized mechanisms are required for assessing the appropriateness of new crops, cultivars, and practices prior to widespread dissemination to farmers. A researcher should be expected to provide evidence of the superior performance of a potential new recommendation, including results from on-farm testing, and its acceptability to farmers who have collaborated in the testing. With respect to the release of new varieties, representatives of research, extension, and seed-production institutions should make recommendations after reviewing the evidence available.

(6) Regional cooperation in crop improvement: Crop improvement programs benefit considerably from contact with related programs in other countries of the region. Opportunities for researchers to meet periodically in the field and to learn from one another's methodologies, mechanisms, and results are recommended as a cost-effective means of strengthening national programs.

(7) Cooperation with international agricultural research centres: Many crop improvement programs have benefited from new germ plasm, information, and training provided by international centres. Further strengthening of these cooperative efforts is desirable. International centres, however, should verify that each cooperative activity responds to a particular need, as expressed by a national program, and, especially in the case of smaller or less developed institutions, that the cooperation takes a form that is compatible with the level of resources available to the national program.

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